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TEST AND EVALUATION OF VHF/UHF ANTENNAS

James G. Dong

Federal Aviation Administration
Atlantic City, New Jersey

November 1968

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FINAL REPORT

Project No. 221-110-16X

TEST AND EVALUATION OF VHF/UHF ANTENNAS

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DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
National Aviation Facilities Experimental Center
Atlantic City, New Jersey 08405

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FINAL REPORT

TEST AND EVALUATION OF VHF/UHF ANTENNAS

PROJECT NO. 221-110-16X

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Prepared by:
JAMES G. DONG

for

SYSTEMS RESEARCH AND DEVELOPMENT SERVICE

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DEPARTMENT OF TRANSPORTATION
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ABSTRACT

This report presents results of tests performed at the National Aviation Facilities Experimental Center (NAFEC) to obtain standard reference antenna patterns for existing Federal Aviation Administration (FAA) and selected prototype VHF and UHF air-ground communication antennas, and associated investigations to determine the effects of antenna configuration, siting, polarization, mutual coupling, and antenna deicing. Because the transmission line is a primary auxiliary to an antenna system, characteristics of foam dielectric cable were investigated for use in field facilities. Results of the test effort provided standard reference patterns for the antennas investigated. In addition, it was determined that the siting environment was the predominant influence on antenna radiation patterns; dissimilar circular polarized antennas could be vertically stacked to provide the needed decoupling where space limitation was a constraint; antenna heaters were feasible for deicing antenna; and foam dielectric cable reduced transmission line losses. It was recommended that dissimilar polarized antennas, heated antennas (where applicable), and foam dielectric cable be used at field facilities.

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INTRODUCTION

Purpose

The purpose of this project effort was fourfold: (1) to measure and document the radiation patterns of prototype and currently operational VHF/UHF communications antennas; (2) to determine the effects of antenna configuration, siting, and polarization of antennas on the radiation patterns; (3) to evaluate the provisions of newly developed UHF antennas and in-house designed modifications to existing VHF and UHF antennas for resistance to icing due to inclement weather conditions; and (4) to determine the performance characteristics, installation procedures, and suitability of foam dielectric cable for use with existing and planned FAA communications facilities.

Background

The FAA has established a continuing program towards in-service improvement of VHF/UHF ground-to-air communications. One facet of this effort has been research and development investigations of improved radiation systems. This report is intended to sustain these investigations by providing a central source of information pertinent to antennas. In addition, the characteristics of transmission lines utilized with antennas and installation techniques for semi-flexible (foam dielectric) cable are provided. The description of items investigated is included under separate headings.

DISCUSSION

Test Procedure and Results

The test procedures and results discussed in this section encompass three categories: antenna reference patterns, antenna siting tests, and evaluation of foam dielectric cable transmission lines.

Antenna Reference Patterns: Horizontal and vertical antenna radiation patterns were obtained at the Antenna Measurements Range (Figure 1) utilizing a Scientific-Atlanta, Inc., Model Number 29-0.1, crossed-log periodic source antenna. This antenna is dual polarized and has capability for operation in the frequency range of 0.1 to 1 GHz. Each radiator consists of two orthogonal linearly polarized elements having separate coaxial outputs and coincident phase centers. Either element may be used independently or both may be used simultaneously. Prior to

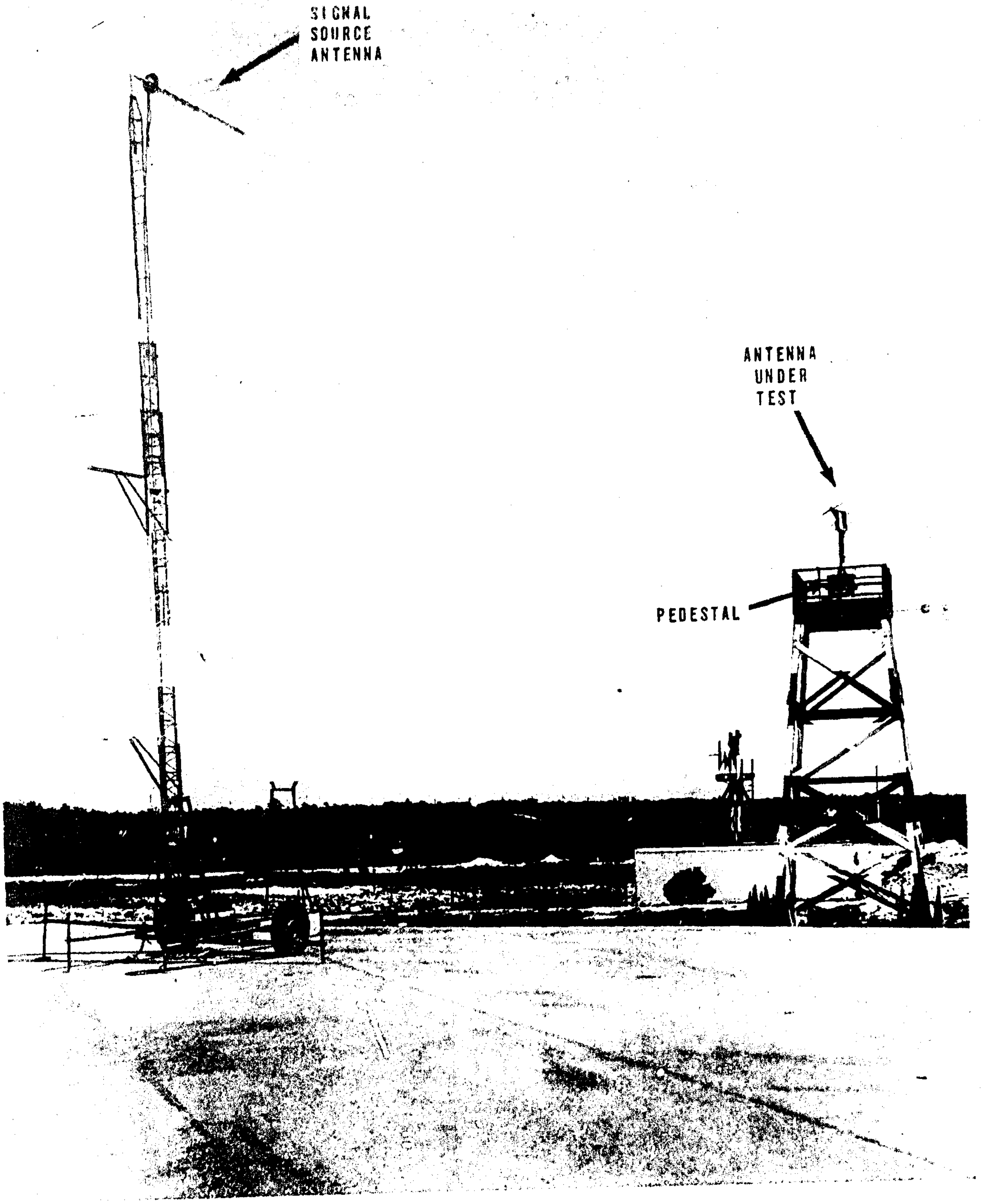

FIG. 1 ANTENNA MEASUREMENTS RANGE

measurements performed on each antenna under test, a reference dipole antenna was positioned to provide a gain of 2.15 dB at the test frequency. (The value of 2.15 dB was used because it is the standard gain for a half wave length dipole with reference to an isotropic antenna.) The antenna under test functioned as the receiving antenna, the source antenna as a transmitting antenna. The horizontal patterns were measured with the antenna under test mounted vertically and rotated in azimuth around its vertical axis. The vertical patterns were measured with the antenna under test mounted horizontally and rotated in azimuth around its electrical center. This initial pattern was the 0^{o} vertical pattern and served as the reference for the other vertical patterns. From this point the antenna was axially rotated 30^{o} for each vertical pattern cut. Patterns were made at 0^{o}, 30^{o}, 60^{o}, 90^{o}, 120^{o} and 150^{o}. Details of the test procedure utilized are contained in Appendix I.

Pattern and gain measurements were accomplished on the following antennas: VHF Swastika, Type CA-1781, a circularly polarized antenna; VHF Coaxial, Type CA-1511; UHF Disc-Cone, Type AT-197; UHF Disc-Cone, Type FA-5668; UHF Collinear Array, Type AS-505; and UHF Collinear Array, Type FA-5676X; all vertically polarized antennas. Horizontal and vertical patterns were measured at the high, low, and mid-band frequency of each antenna. Only one horizontal and vertical pattern for each type antenna tested has been included in the report; however, a complete set of antenna patterns is on file at NAFEC and may be obtained for inspection.

Type CA-1781 Antenna -

A. Description - The Type CA-1781 Swastika circular polarized Antenna (Figure 2) is used for ground-to-air transmission in the VHF frequency range of 118 to 135 MHz. The antenna utilizes four half wave length dipole elements spaced at approximately 1/3 wave length at mid-band frequency. Each dipole is inclined 30^{o} from the horizontal plane. The dipole elements are connected in one piece to the central support body or hub by means of parallel transmission lines of approximately 200 ohms impedance. The antenna RF input connector is located at the base of the antenna inside of the hub.

The antenna, fabricated of solid aluminum alloy 43, weighs 20 pounds. It is designed for a wind load of 100 miles per hour with one-half inch of radial ice.

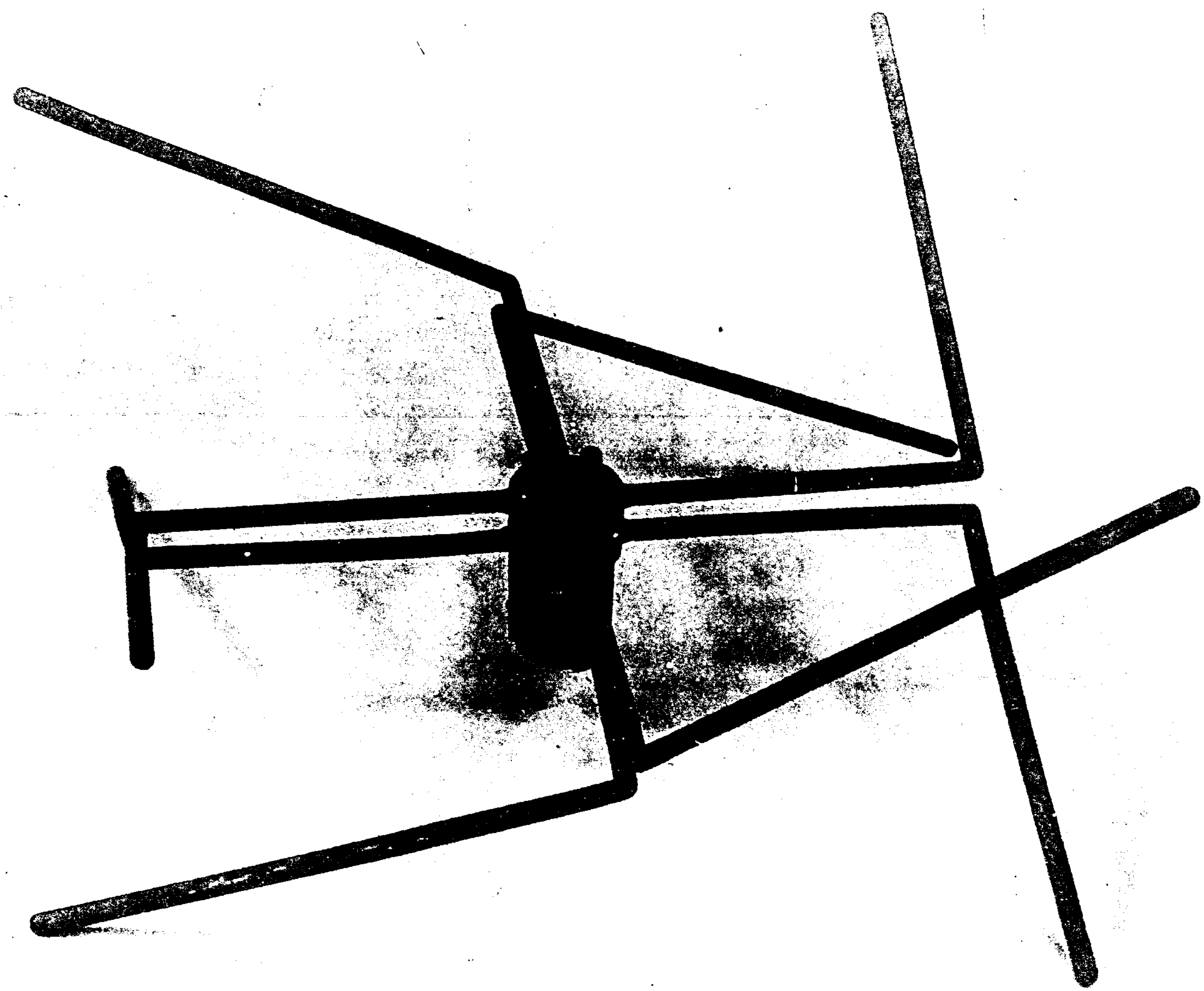

FIG. 2 VHF SWASTIKA ANTENNA TYPE CA-1781

B. Characteristics - The antenna has the following nominal electrical characteristics:[1]

(1) Frequency Range: 118 to 135 MHz
(2) Impedance: 50 ohms
(3) Polarization: Circularly clockwise
(4) Power Rating: 200 RF watts, continuous[2]
(5) Lightning Protection: Adjustable, grounded spark gap
(6) Voltage Standing Wave Ratio: 1.8:1 Maximum

The antenna gains (compared to the standard dipole gain, 2.15 dB) for three test frequencies determined from the pattern measurements are listed in Table I. A sample horizontal pattern (Figure 3) and vertical pattern (Figure 4) are also presented to further define the antenna characteristics.

TABLE I

ANTENNA GAINS

SWASTIKA TYPE CA-1781

Frequency (MHz)	Horizontal Plane (dB)
118	-3.3
124	-1.8
135	-4.3

Type CA-1511 Antenna -

A. Description - The Type CA-1511 Coaxial vertical polarized Antenna (Figure 5) is used for air-to-ground reception in the VHF frequency range of 130 to 140 MHz. The vertical dipole, which is unbalanced with respect to ground, consists of an upper pole or radiator and a lower pole or skirt with a total length of 43 inches dimensioned to a half wave at the median frequency. The antenna RF input connector is located inside of the skirt.

---

[1]All Products Company, Instruction Pamphlet, Circularly Polarized Antenna, Type CA-1781, Mineral Wells, Texas, June 1958.

[2]Federal Aviation Agency Specification, Antenna, VHF Circularly Polarized, FAA-E-2019, Washington, D.C., September 1963.

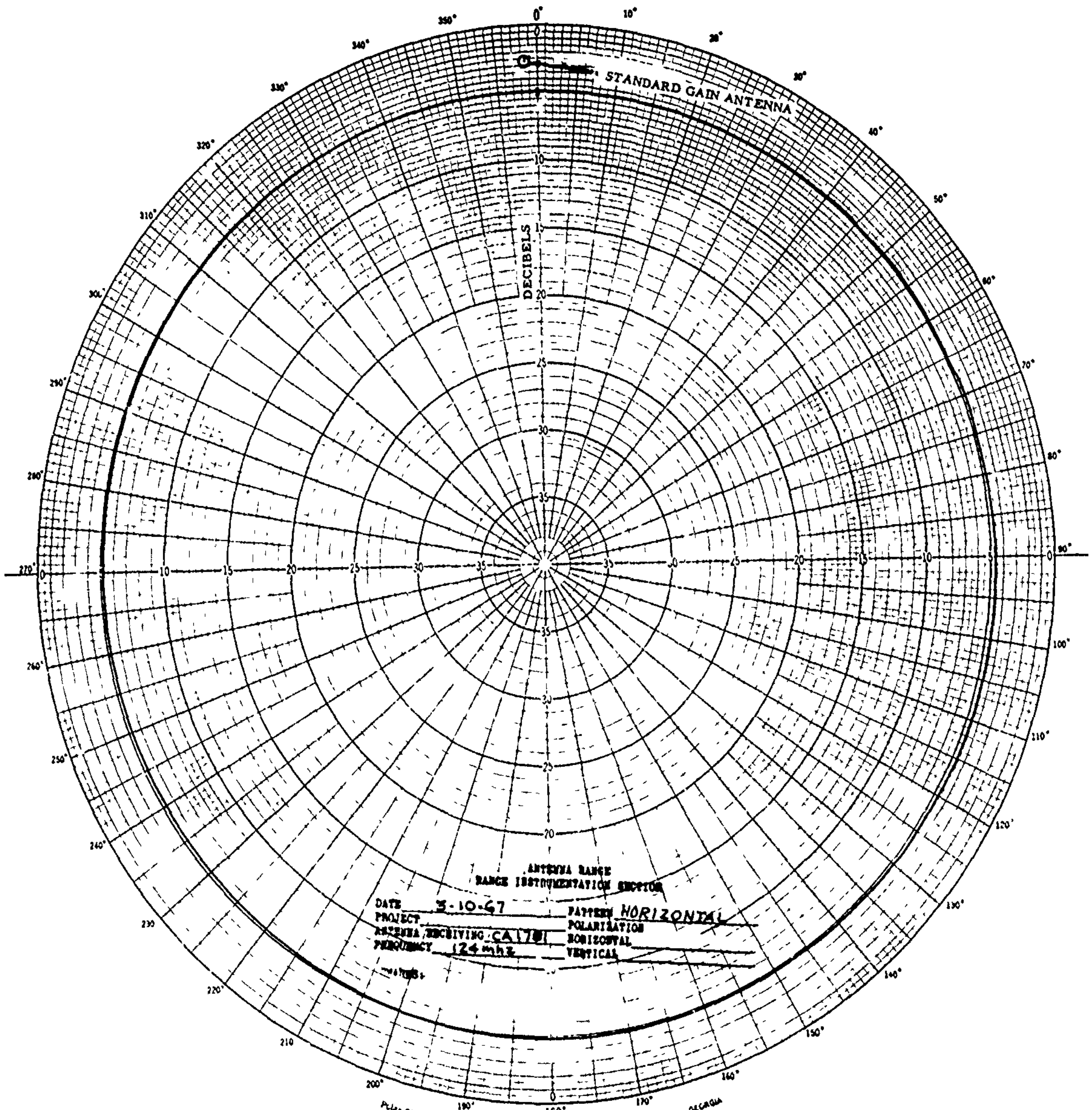

FIG. 3 HORIZONTAL PATTERN OF VHF SWASTIKA ANTENNA TYPE CA-1781

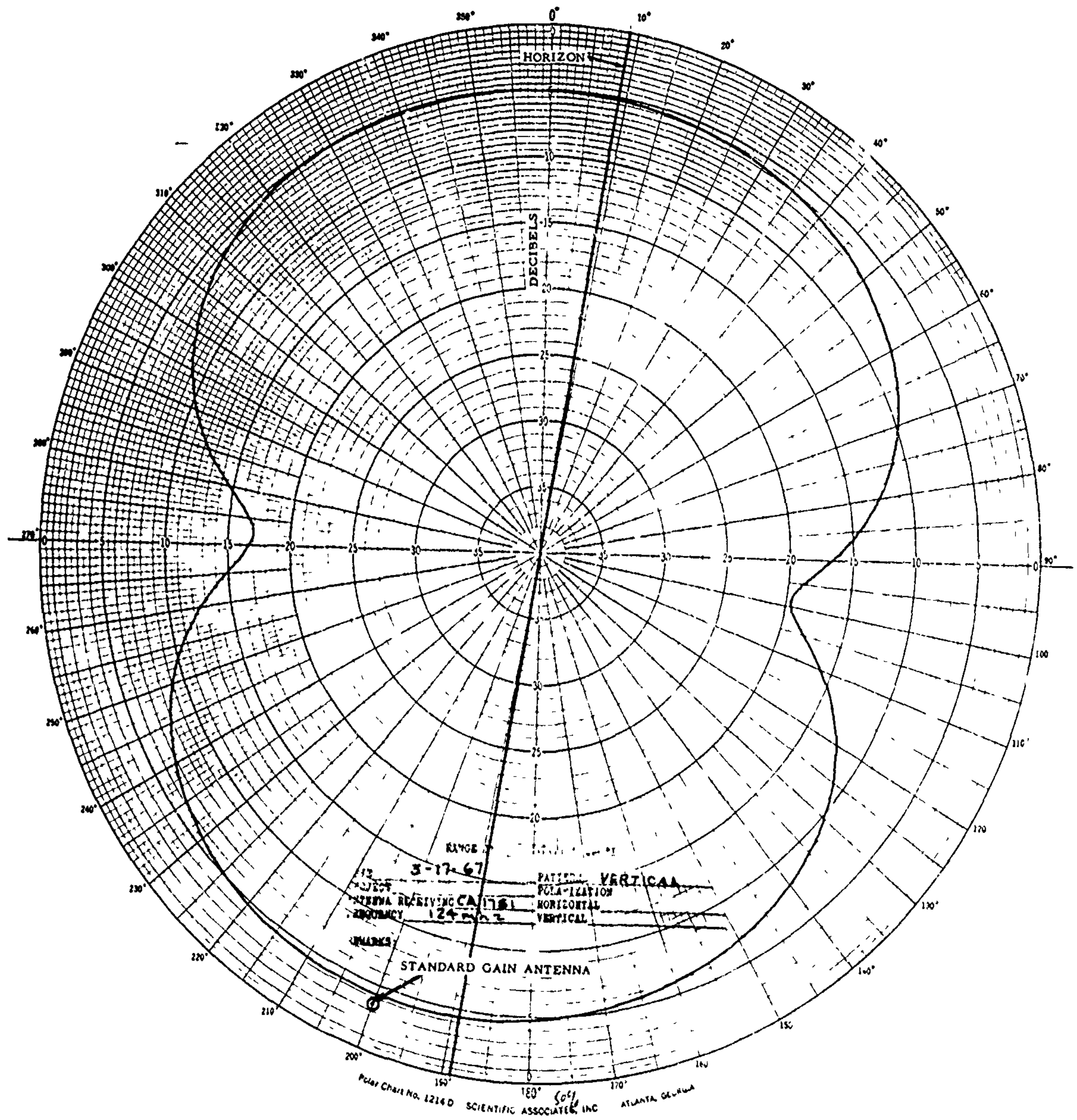

FIG. 4 VERTICAL PATTERN OF VHF SWASTIKA ANTENNA TYPE CA-1781

FIG. 5 VHF COAXIAL ANTENNA TYPE CA-1511

The antenna is fabricated from corrosion resistant materials, mainly aluminum. The antenna is light in weight, 5 pounds, but is constructed to withstand heavy wind and ice loads.

B. Characteristics - The antenna has the following nominal electrical characteristics:[3]

(1) Frequency Range: 130-140 MHz
(2) Impedance: 50 ohms
(3) Polarization: Vertical
(4) Voltage Standing Wave Ratio: 2:1 Maximum

The antenna gains determined from the pattern measurements are listed in Table II. A sample horizontal pattern (Figure 6) and vertical pattern (Figure 7) are also presented to further define the antenna characteristics.

TABLE II

ANTENNA GAINS

COAXIAL TYPE CA-1511

Frequency (MHz)	Horizontal Plane (dB)
132	-3.3
135	0.8
140	-4.0

Type AT-197/GR Antenna -

A. Description - The Type AT-197/GR Disc-Cone vertical polarized broadband Antenna (Figure 8) is used for ground-air-ground communications in the frequency range of 225 to 400 MHz. The disc-cone is composed of a simulated disc and cone separated by a glass insulator. The "disc" and "cone" sections of the antenna are each formed by 12 protruding lengths of hollow, round stock. The disc is mounted horizontally above the cone. The RF input connector is located at the bottom of the antenna support shaft.

[3] Chisholm-Ryder Company, Inc., Instruction Pamphlet, VHF Coaxial Antenna, Type CA-1511, Niagra Falls, New York, 1953

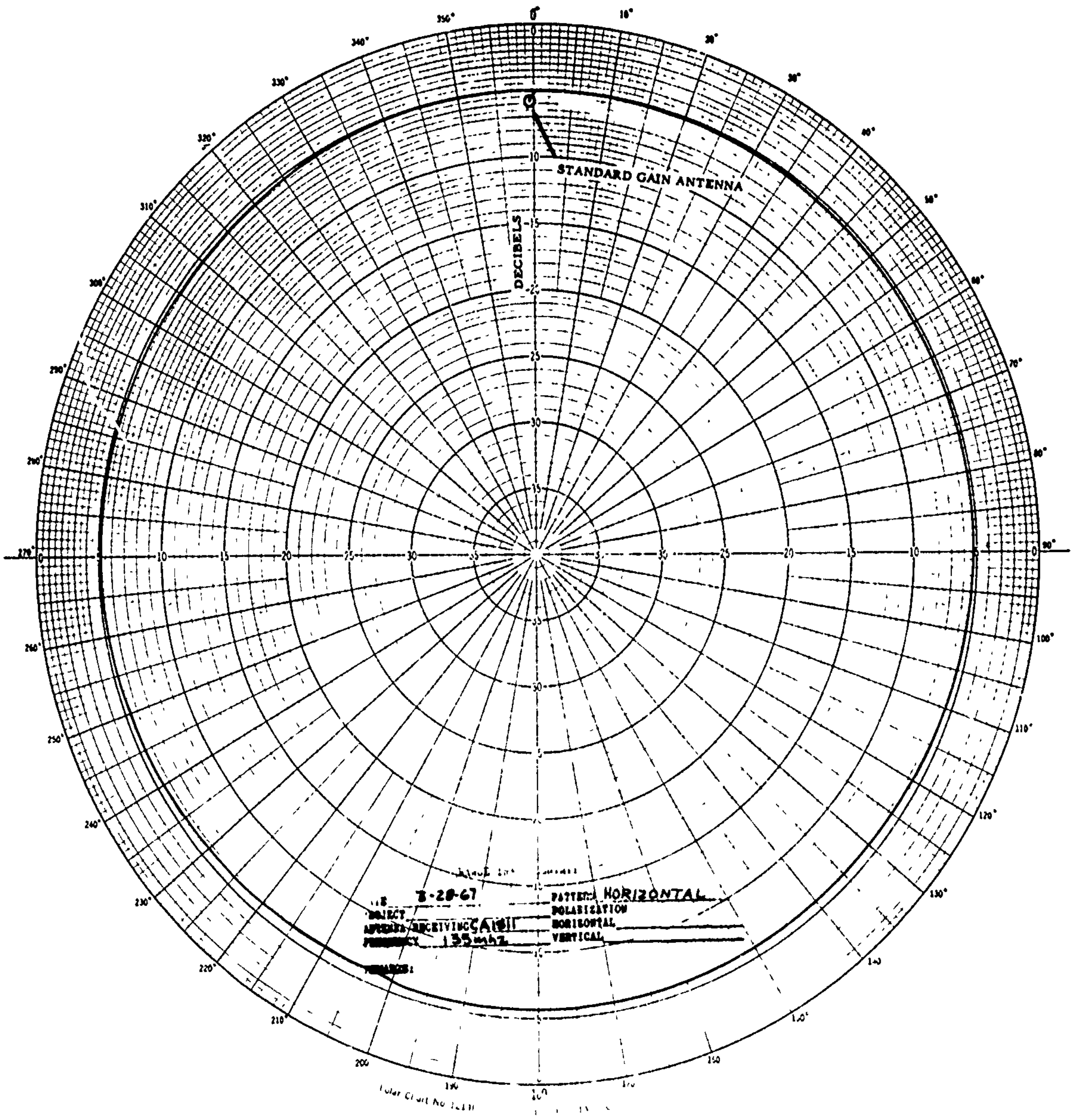

FIG. 6 HORIZONTAL PATTERN OF VHF COAXIAL ANTENNA TYPE CA-1511

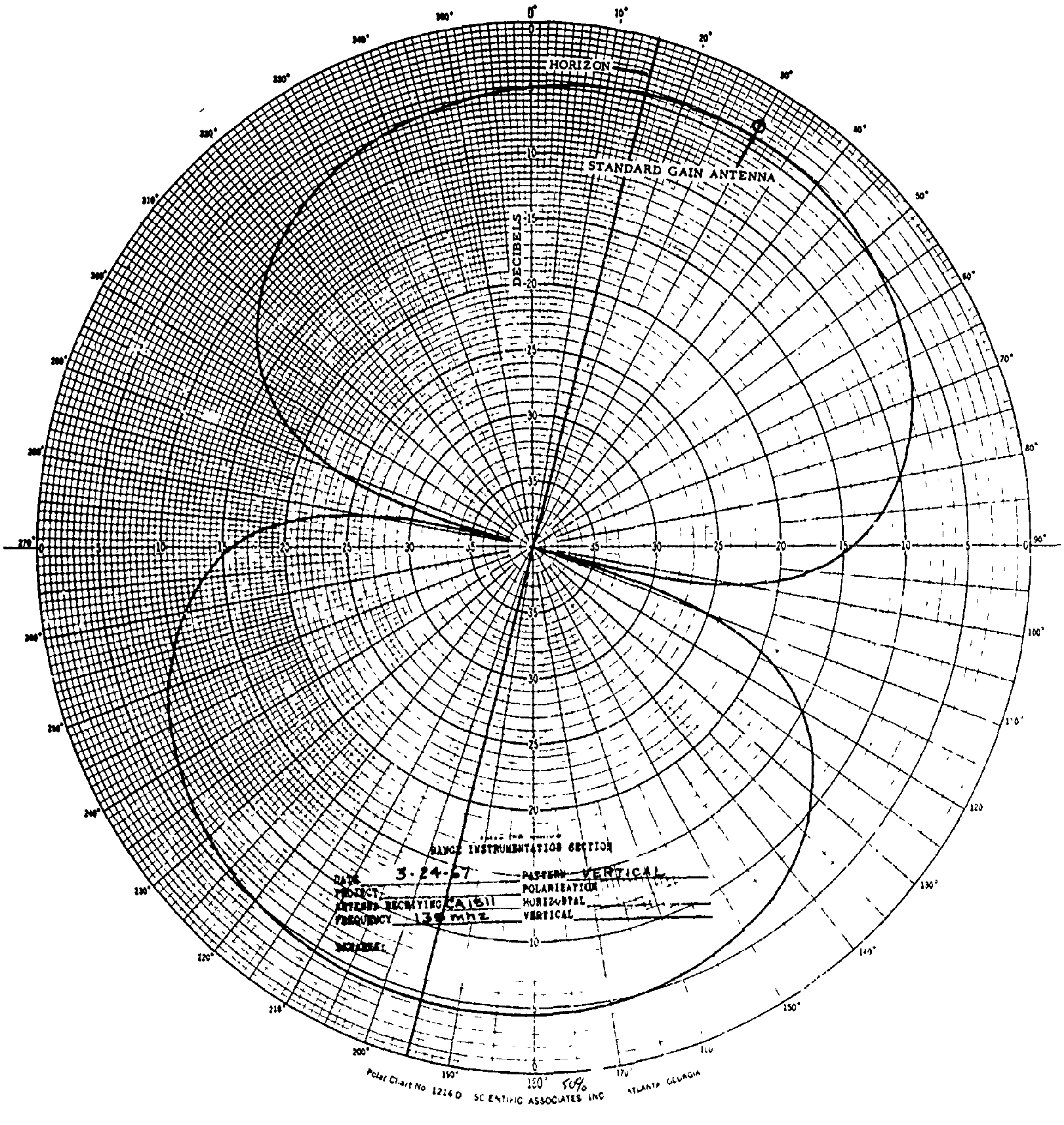

FIG. 7 VERTICAL PATTERN OF VHF COAXIAL ANTENNA TYPE CA-1511

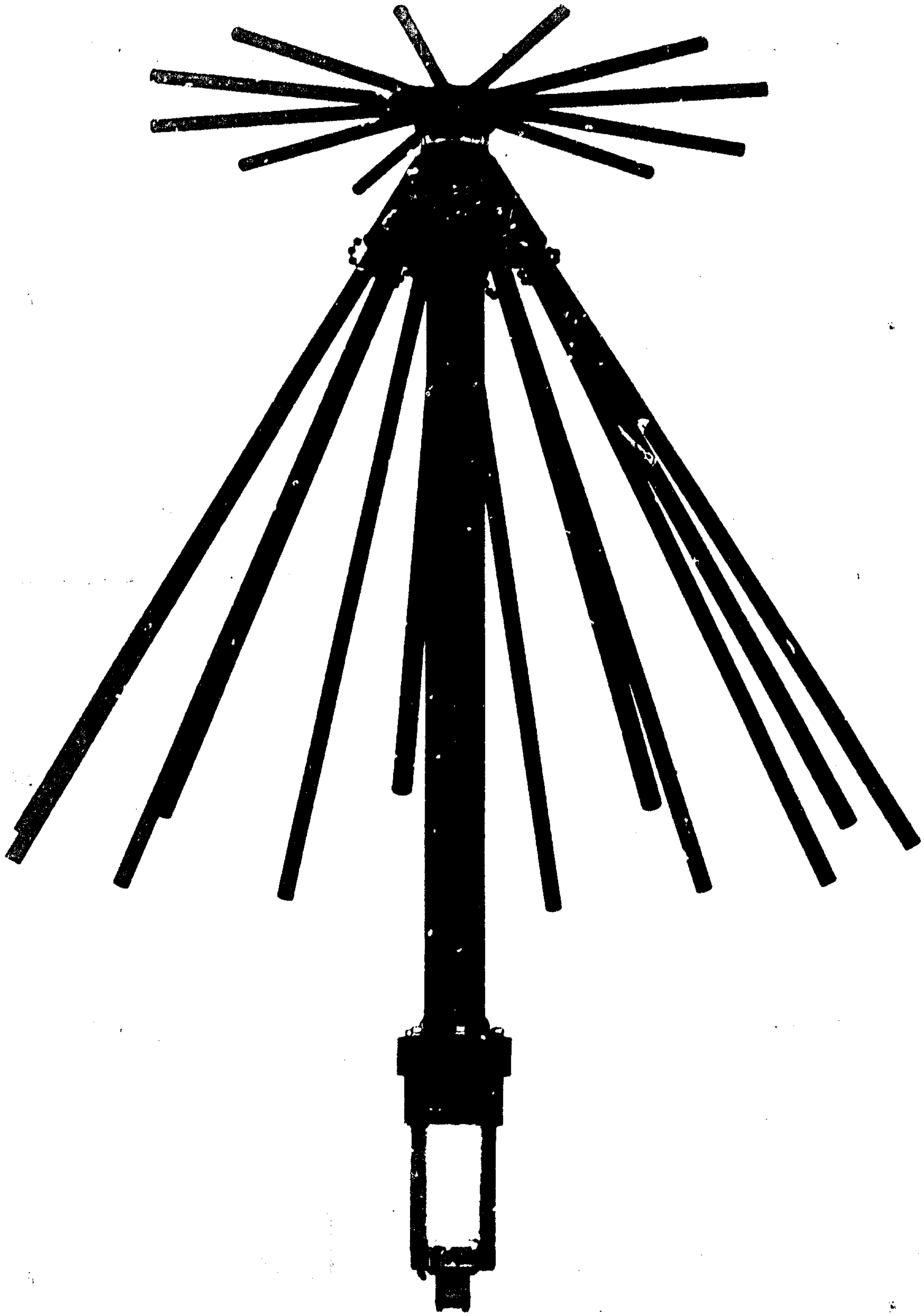

FIG. 8 UHF DISC-CONE ANTENNA TYPE AT-197

The antenna is designed with an overall height of 29 inches and a maximum diameter of 19 inches. The antenna is light in weight, 6 pounds, but the open framework construction permits it to withstand heavy wind and ice loads.

B. Characteristics - The antenna has the following nominal electrical characteristics:[4]

(1) Frequency Range: 225 to 400 MHz
(2) Impedance: 50 ohms
(3) Polarization: Vertical
(4) Power Rating: 1000 RF watts
(5) VSWR: 1.6:1 Maximum

The antenna gains determined from the pattern measurements are listed in Table III. A sample horizontal pattern (Figure 9) and vertical pattern (Figure 10) are also presented to further define the antenna characteristics.

TABLE III

ANTENNA GAINS

DISC-CONE TYPE AT-197

Frequency (MHz)	Horizontal Plane (dB)
225	-1.0
300	-1.0
400	-1.0

Type FA-5668 Antenna -

A. Description - The Type FA-5668 Disc-Cone vertical polarized broadband Antenna (Figure 11) is used for ground-air-ground communications in the frequency range of 225 to 400 MHz. The radiating disc is attached to the insulator with six screws thus completing electrical contact to the center pin of the UG 680/U connector.

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[4] J & H Smith Manufacturing Company, Installation Instructions For Antenna Assembly AT-197/GR. September 1957.

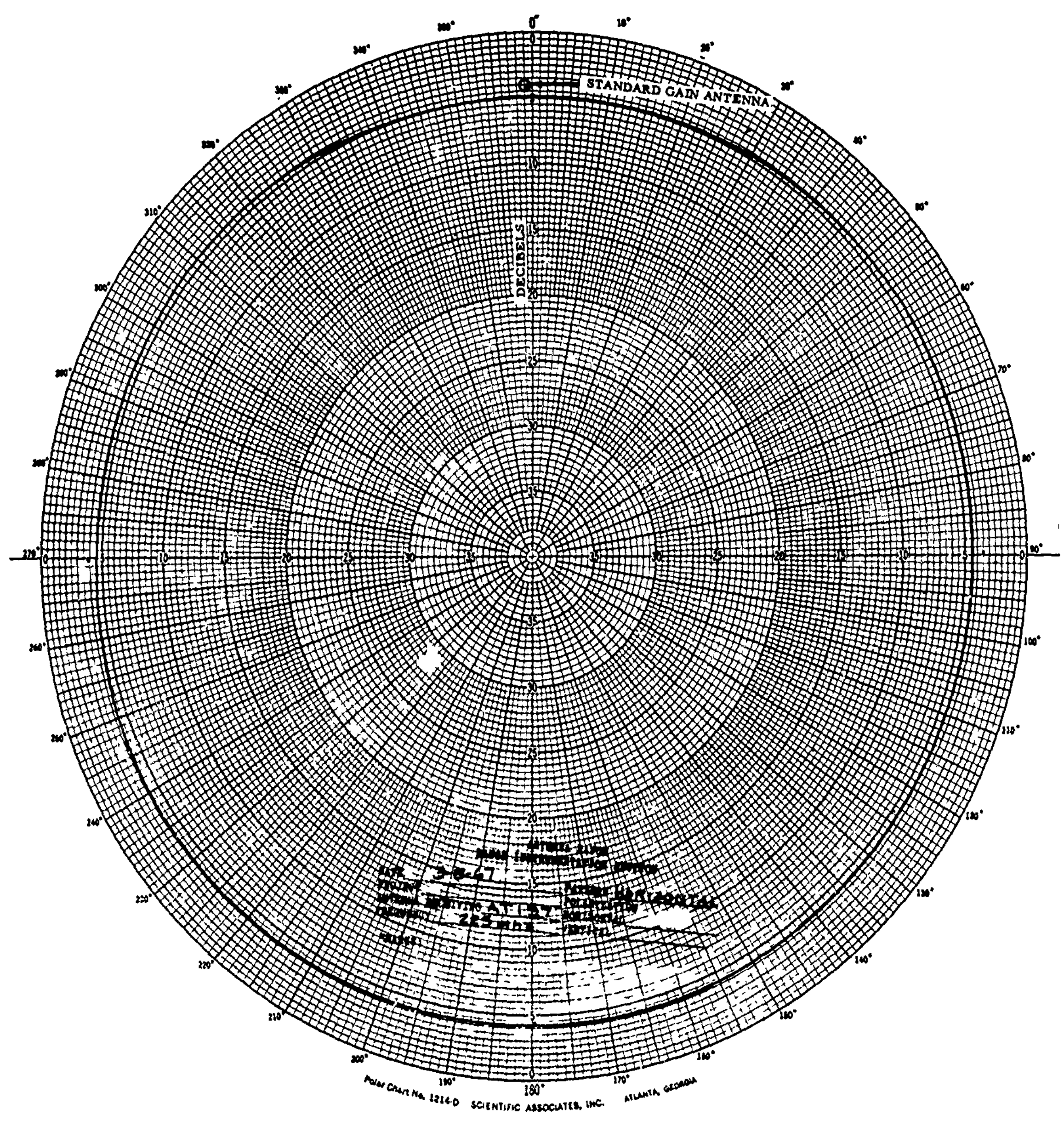

FIG. 9 HORIZONTAL PATTERN OF UHF DISC-CONE ANTENNA TYPE AT-197

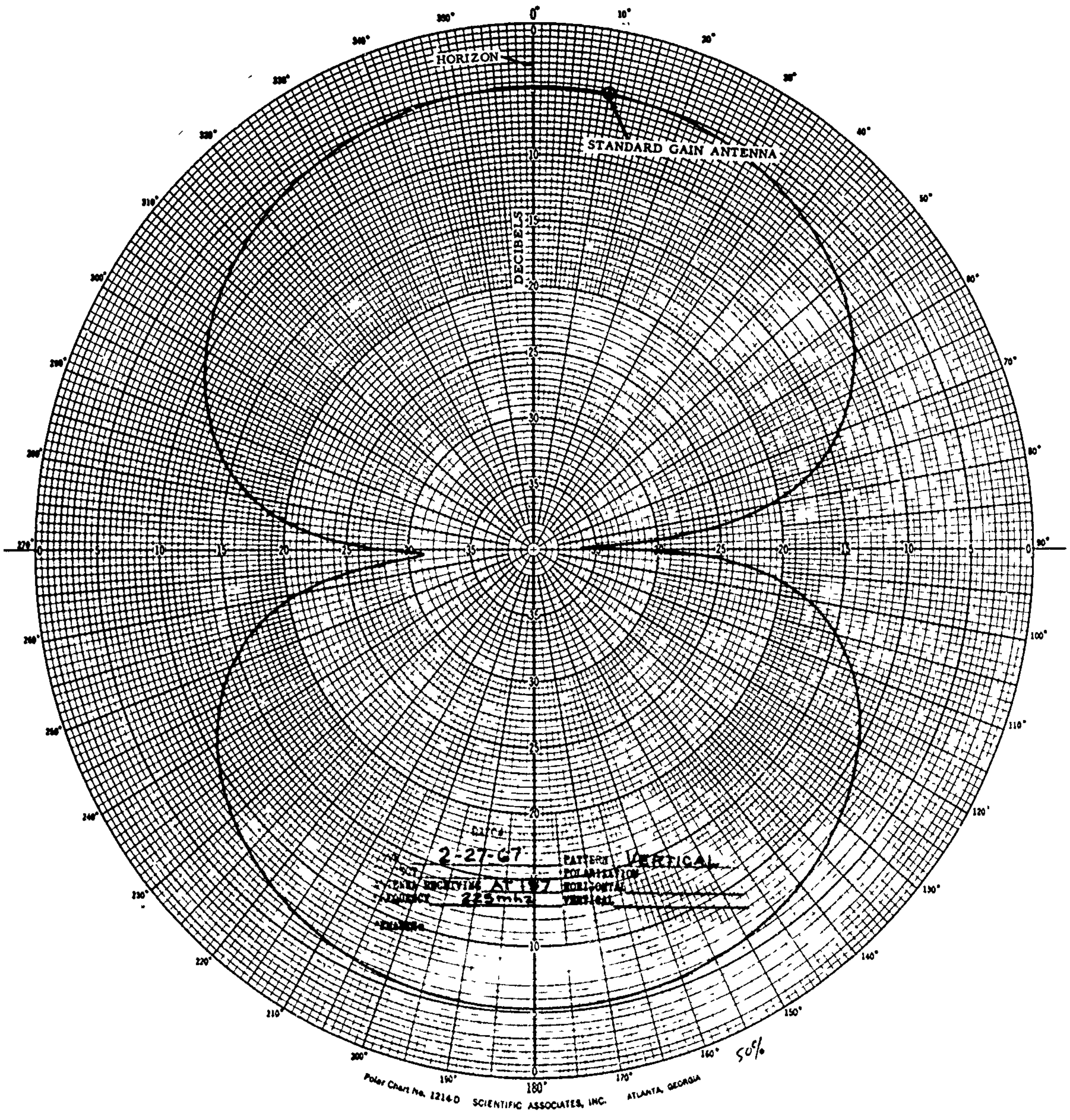

FIG. 10 VERTICAL PATTERN OF UHF DISC-CONE ANTENNA TYPE AT-197

FIG. 11 UHF DISC-CONE ANTENNA TYPE FA-5668

The insulator is fabricated with glass reinforced plastic and is mounted to the hub by four screws. Six element rods screw into the hub which give the antenna a cone shape.

The antenna weighs 4 1/2 pounds and has overall dimensions of 15 3/8 inches in height and 18 5/8 inches in diameter.

B. Characteristics - The antenna has the following nominal electrical characteristics:[5]

(1) Frequency Range: 225 to 400 MHz
(2) Impedance: 50 ohms
(3) Polarization: Vertical
(4) Power Rating: 1000 RF watts
(5) VSWR: 1.8:1

The antenna gains determined from the pattern measurements are listed in Table IV. A sample horizontal pattern (Figure 12) and vertical pattern (Figure 13) are also presented to further define the antenna characteristics.

TABLE IV

ANTENNA GAINS

DISC-CONE TYPE FA-5668

Frequency (MHz)	Horizontal Plane (dB)
225	-0.8
300	0.5
400	-3.0

Type AS-505A/GR Antenna -

A. Description - The AS-505A/GR vertical polarized collinear array, high gain, broadband Antenna (Figure 14) is used for ground-air-ground communications in the frequency range of 225 to 400 MHz. The antenna has four vertically stacked "squirrel-cage" bays

[5] Antenna Products Company, Instruction Booklet, UHF, Disc-Cone Antenna, Type FA-5668, Mineral Wells, Texas, March 1965.

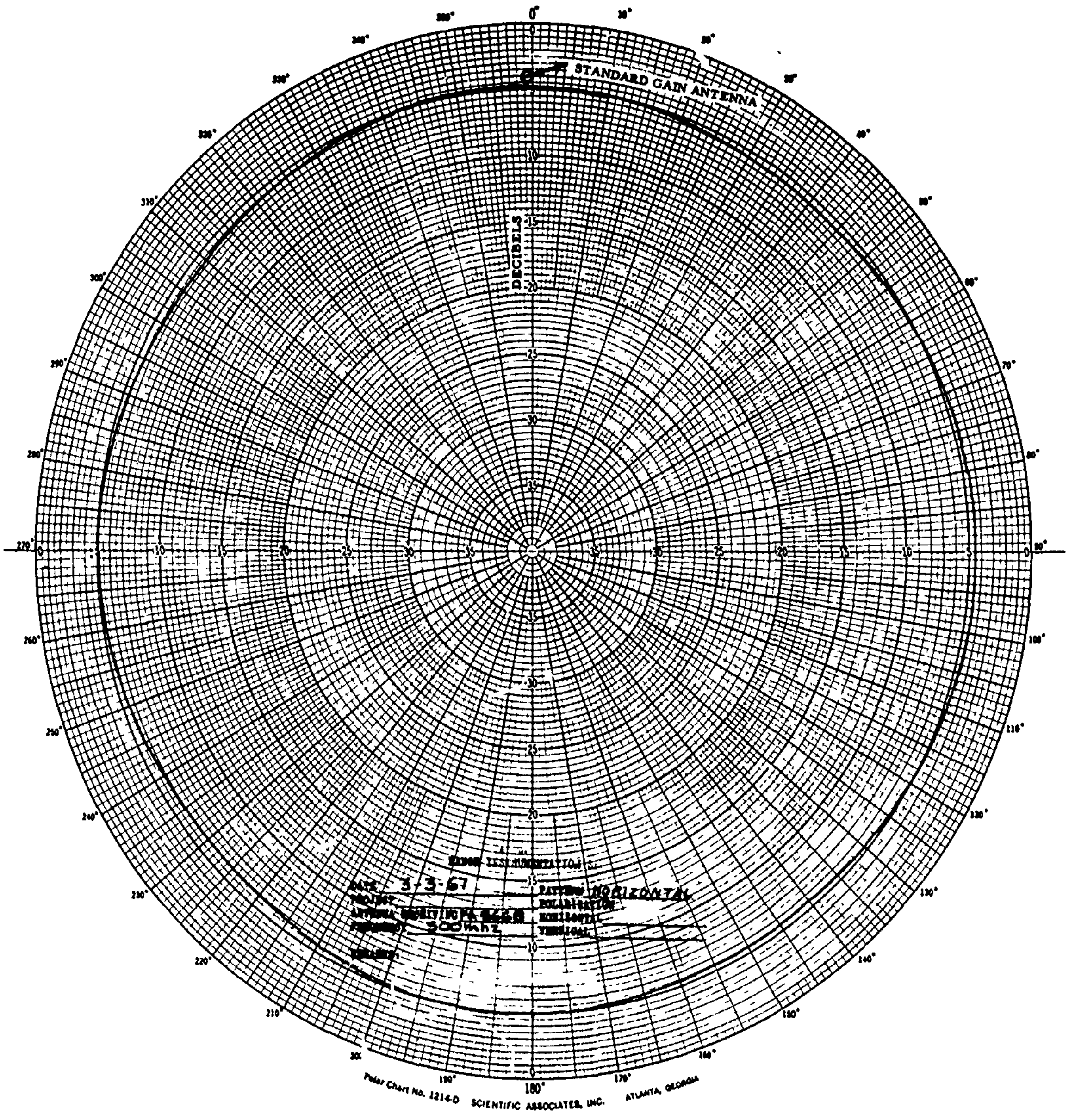

FIG. 12 HORIZONTAL PATTERN OF UHF DISC-CONE ANTENNA TYPE FA-5668

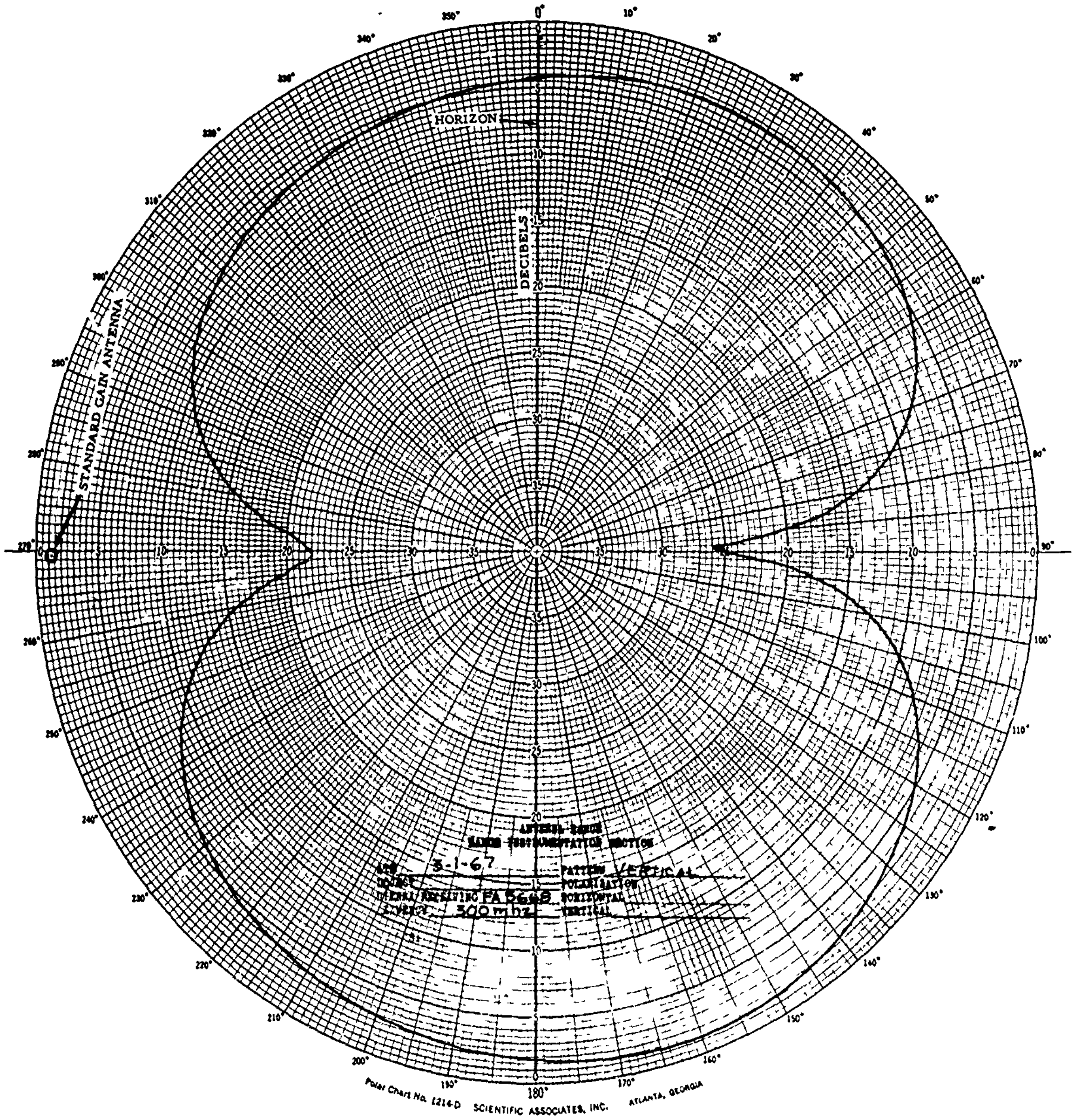

FIG. 13 VERTICAL PATTERN OF UHF DISC-CONE ANTENNA TYPE FA-5668

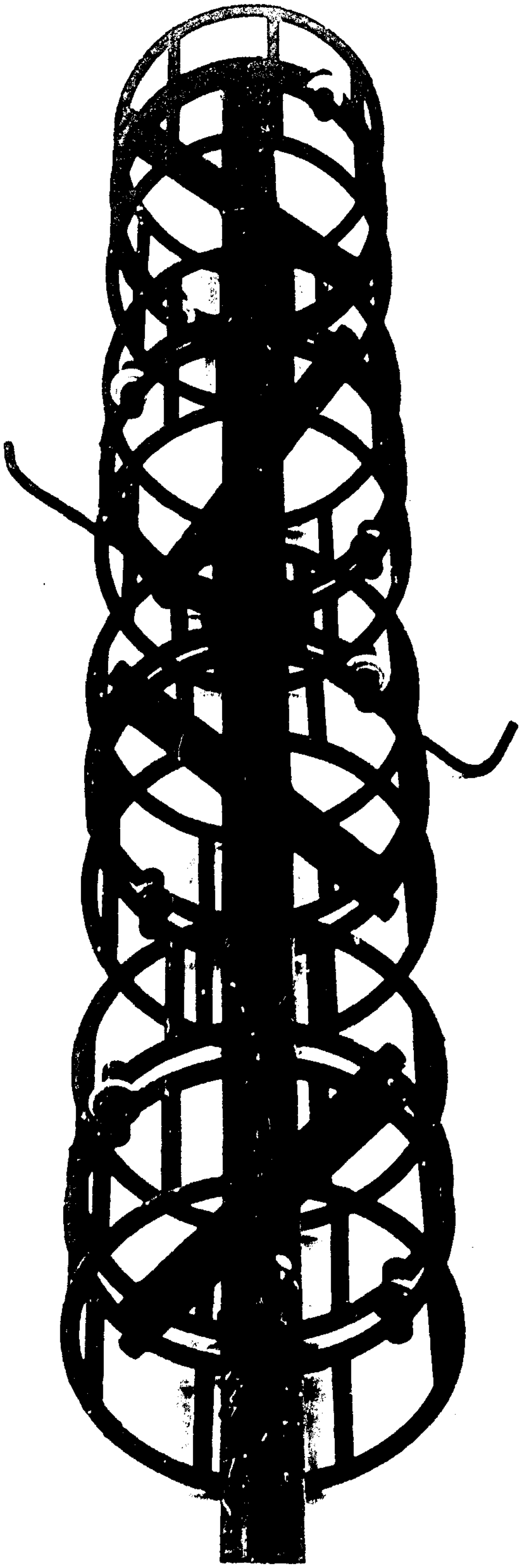

FIG. 14 UHF COLLINEAR ARRAY ANTENNA TYPE AS-505 A/GR

(four dipoles). Each bay is fed at two points to obtain omnidirectional radiation in the horizontal plane. The antenna RF input connector is located inside of the support shaft at a tube joint.

The antenna's overall height is 156 inches, the bay diameter is approximately 15 inches, and the net weight is 56 pounds. The antenna is designed to withstand heavy winds.

B. Characteristics - The antenna has the following nominal electrical characteristics:[6]

(1) Frequency Range: 225 to 400 MHz
(2) Impedance: 52 ohms
(3) Polarization: Vertical
(4) VSWR: 2:1 Maximum

The antenna gains determined from the pattern measurements are itemized in Table V. A sample horizontal pattern (Figure 15) and vertical pattern (Figure 16) are also presented to further define the antenna characteristics.

TABLE V

ANTENNA GAINS

COLLINEAR ARRAY, TYPE AS-505A/GR

Frequency (MHz)	Horizontal Plane (dB)
225	2.3
300	-2.5
400	-1.8

Scanwell Type FA-5676X Antenna -

A. Description - The Scanwell Laboratories, Inc., Type FA-5676X vertical polarized Antenra (Figure 17) is used for air-ground

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[6] Air Force Technical Manual, T.O. 31R-1-8, Section X, Radio Antennas (VHF-UHF), pages 10-28.

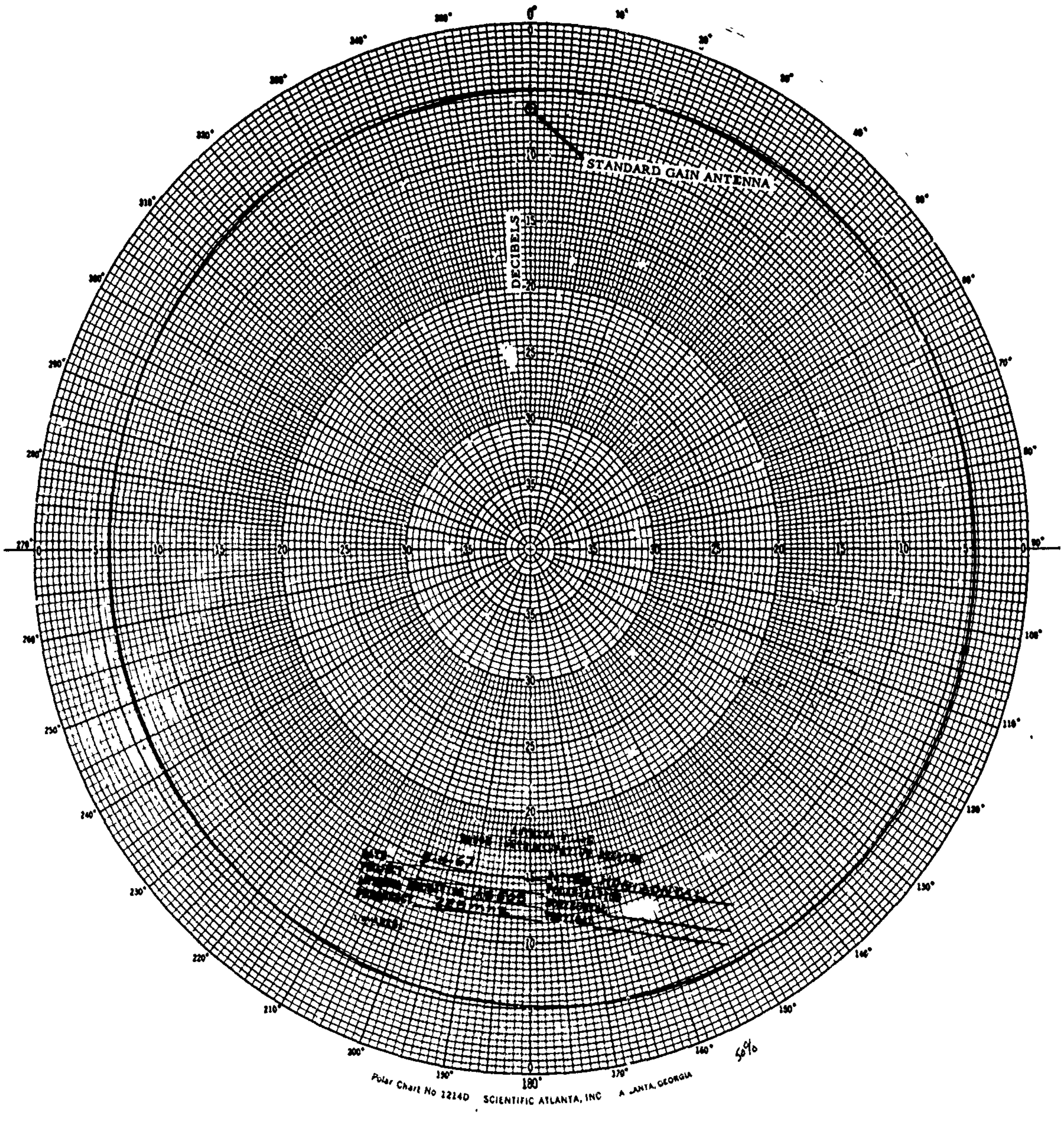


FIG. 15 HORIZONTAL PATTERN OF UHF COLLINEAR ARRAY ANTENNA TYPE AS-505 A/GR

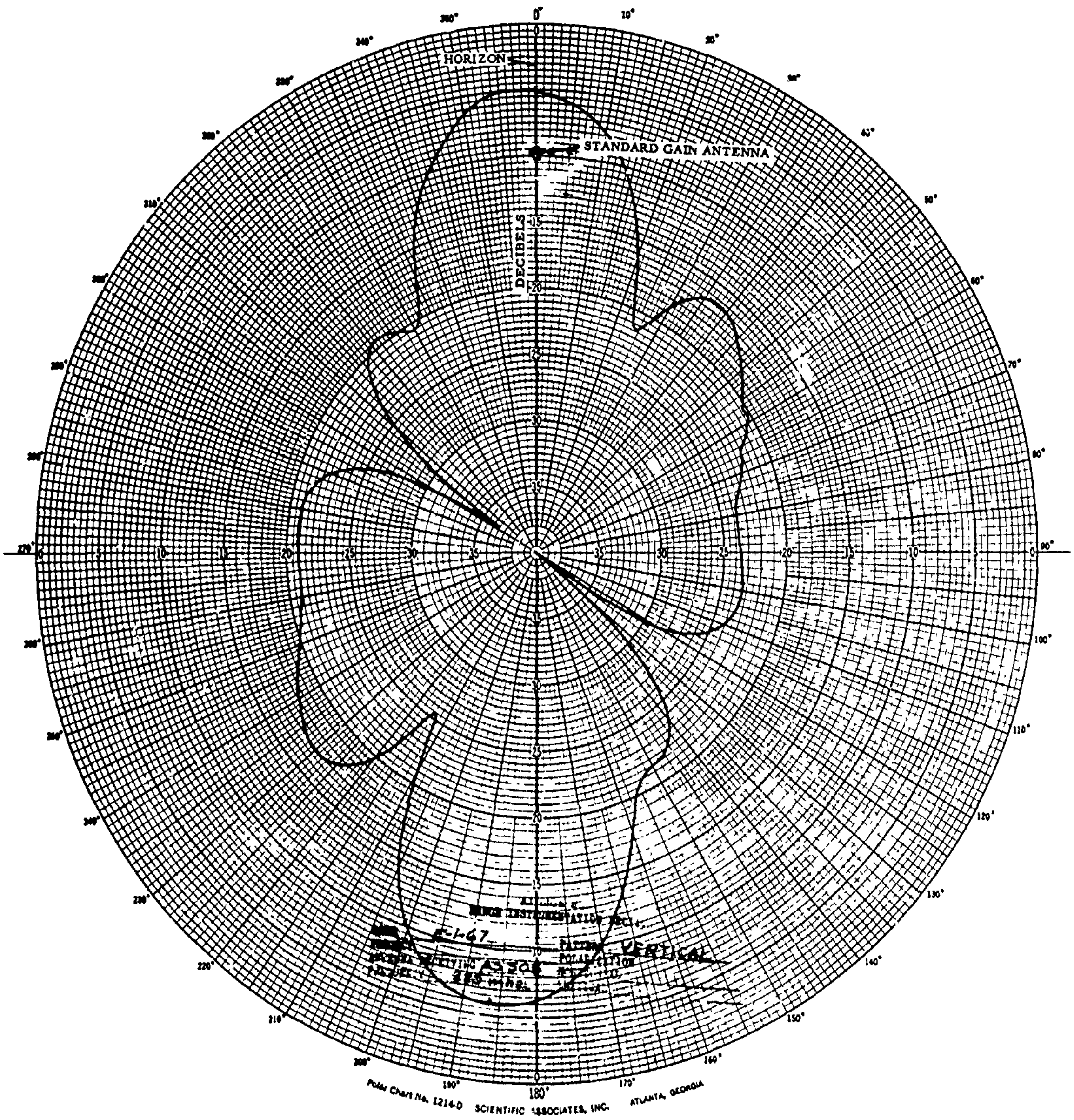


FIG. 16 VERTICAL PATTERN OF UHF COLLINEAR ARRAY ANTENNA TYPE AS-505 A/GR

FIG. 17 UHF COLLINEAR ARRAY ANTENNA TYPE FA-5676X

communications in the frequency range of 225 to 400 MHz. The antenna consists of vertical dipole elements which are phased with current distribution to produce the necessary vertical pattern and vertical beam tilt. The antenna is housed in a Fiberglas tube which provides mechanical support and isolates the radiating elements, feed points, and transmission lines from weather. Heating elements distribute 1200 watts of heat throughout the tube. A thermostat is located within the antenna to operate only during icing temperatures (below 40°F).

The antenna overall height is 12 feet 10 inches, the housing diameter is 4 inches, and the net weight is 35 pounds. Included in the base are mounting holes for attaching the antenna to the platform rails of the antenna towers used in Remote Center Air-Ground Facilities (RCAG).

B. Characteristics - The antenna has the following nominal electrical characteristics:

(1) Frequency Range: 225 to 400 MHz
(2) Impedance: 52 ohms
(3) Polarization: Vertical
(4) VSWR: 2:1 Maximum
(5) Heater: 1200 watts, 115 volts, 60 cycle AC
(6) Thermostat Control: Normally closed; open for temperatures above 40°F

The antenna gains determined from the pattern measurements are listed in Table VI. A sample horizontal pattern (Figure 18) and vertical pattern (Figure 19) are also presented to further define the antenna characteristics:

TABLE VI

ANTENNA GAINS

COLLINEAR ARRAY TYPE FA-5676X

Frequency (MHz)	Horizontal Plane (dB)
225	-3.8
300	0.3
400	-1.5

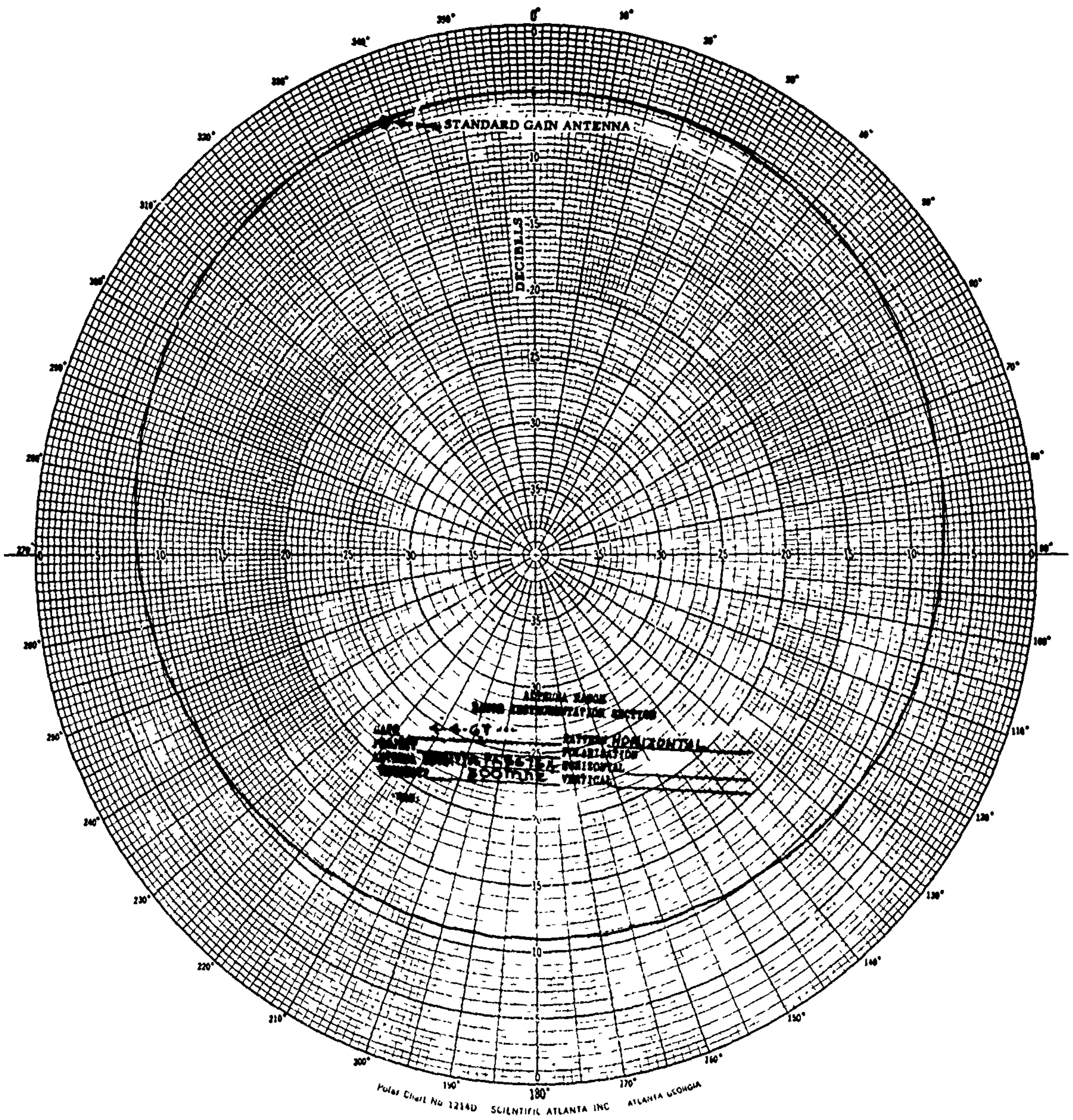


FIG. 18 HORIZONTIAL PATTERN OF UHF COLLINEAR ARRAY ANTENNA TYPE FA-5676X

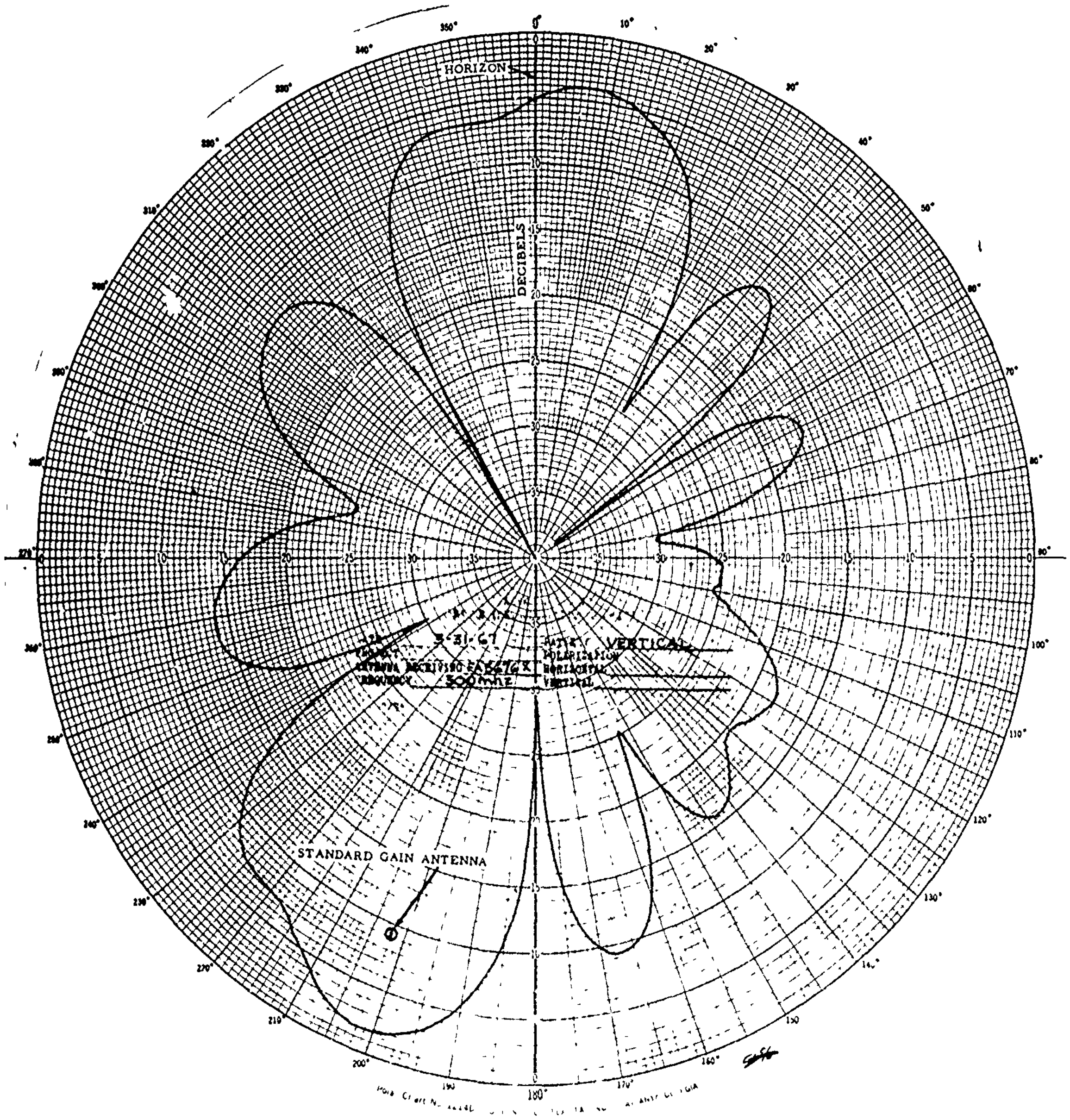


FIG. 19 VERTICAL PATTERN OF UHF COLLINEAR ARRAY ANTENNA TYPE FA-5676X

Antenna Siting Tests: Antenna siting tests were accomplished to determine antenna characteristics under an operational environment. These tests included orbital and radial flight tests; intercoupling and polarization tests; noise (ignition type) susceptibility; and inclement weather tests (icing) on antennas at RCAG sites.

Orbital and Radial Flight Tests - Orbital flights of 20 nautical miles (nmi) radius and north to south and east to west radials were accomplished to obtain radiation patterns of the ground antennas under test. The FAA Grumman Gulfstream aircraft N-376 (Figure 20) was used for the tests. Figure 21 shows the location of project test antennas on the aircraft which were utilized for the tests. The horizontal polarized VHF antenna was a Collins Type 37J-3 with a frequency range of 108 to 122 MHz. and the vertically polarized VHF antenna was a Collins Type 37R-1 with a frequency range of 118 to 136 MHz. For the frequency range of 225-400 MHz, a vertically polarized Type AT-256 UHF Antenna was utilized. The flight tests were performed as follows:

A. Type CA-1781 Antenna - RF transmissions were made from a Type CA-1781 VHF Swastika Antenna installed in a normal configuration at the Experimental Peripheral Communications Facility. Radiation patterns were recorded in the aircraft for horizontal and vertical polarized signals of 118. 15 and 134. 9 MHz, respectively. The orbital flights were performed at aircraft altitudes of 1500 and 15, 000 feet while the radials were performed only at an altitude of 15, 000 feet.

Graphic presentation of the test results are shown in Figures 22 and 23. As shown in Figure 22, the area of coverage was more symmetrical (omnidirectional) when a vertically polarized receiving antenna was utilized at flight altitudes of 1, 500 and 15, 000 feet. Although numerous lobes are evident in the patterns the relative signal variations (maxima and minima) are minor. When the horizontally polarized antenna was employed, there was a degradation of the pattern symmetry as compared with vertically polarized antenna patterns. The radial pattern of Figure 23 shows the signal level variations above minimum level as received at the aircraft while it was transversing the test site at an altitude of 15, 000 feet. Maximum signal levels occurred at 5 nmi, north to south outbound to the site, and 7 nmi inbound in the east to west direction for the frequency 118. 15 MHz and horizontally polarized signals. For vertically polarized signals at the aircraft, maximum signals occurred from 2 to 6 nmi inbound, in the north to south direction and 4 nmi outbound, east to west direction.

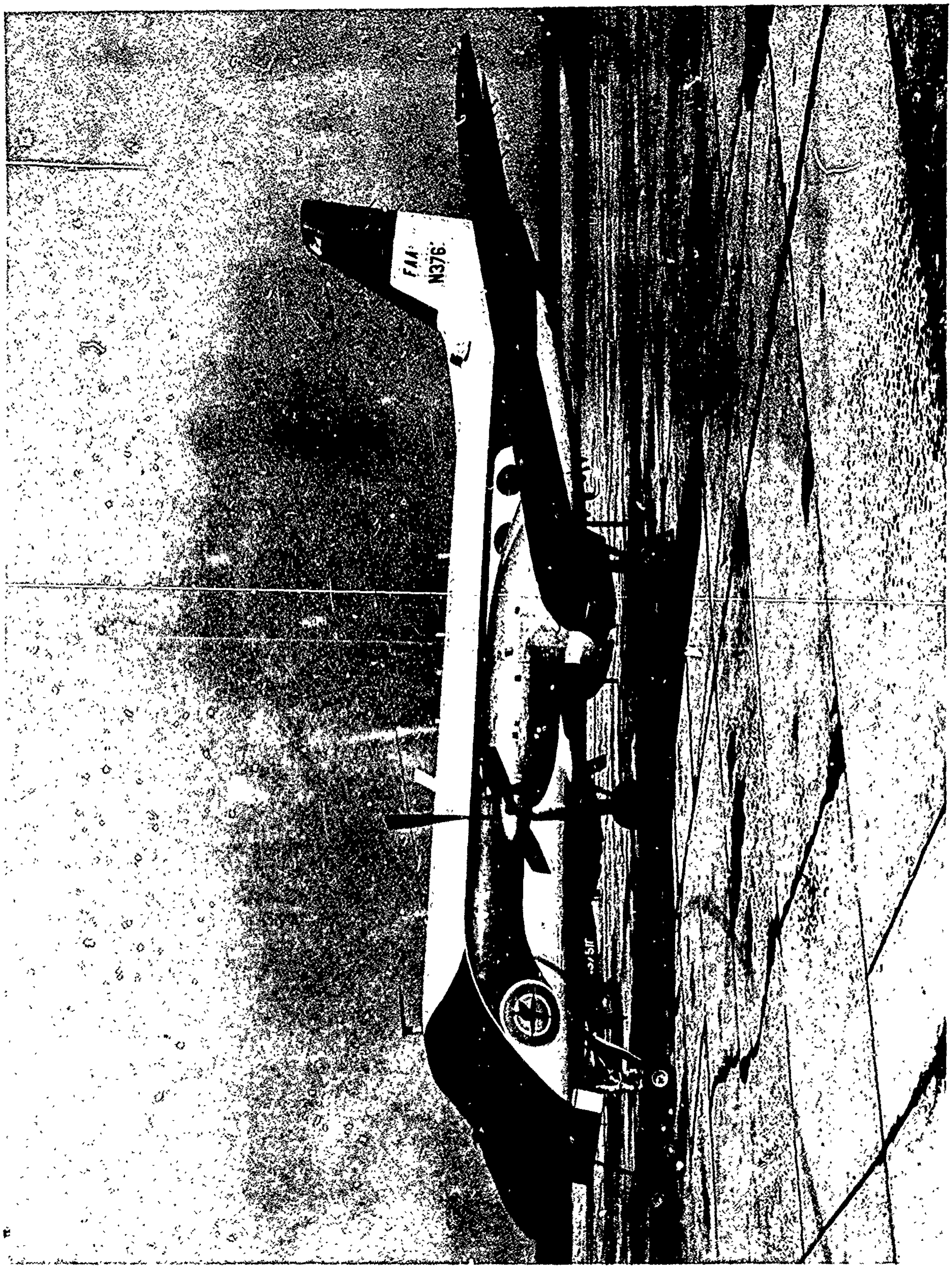


FIG. 20 GRUMMAN GULFSTREAM AIRCRAFT

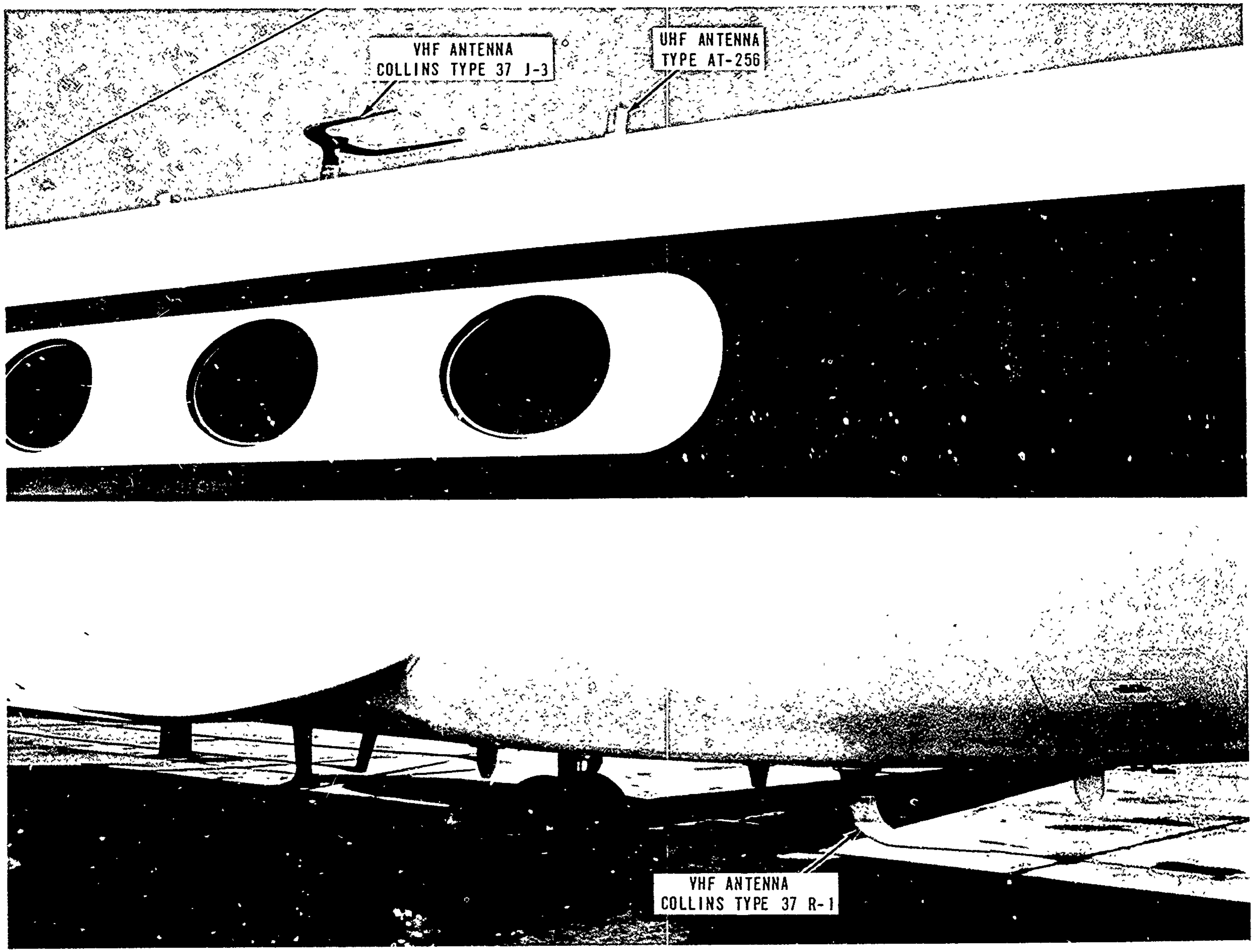


FIG. 21 LOCATION OF TEST ANTENNAS ON PROJECT AIRCRAFT

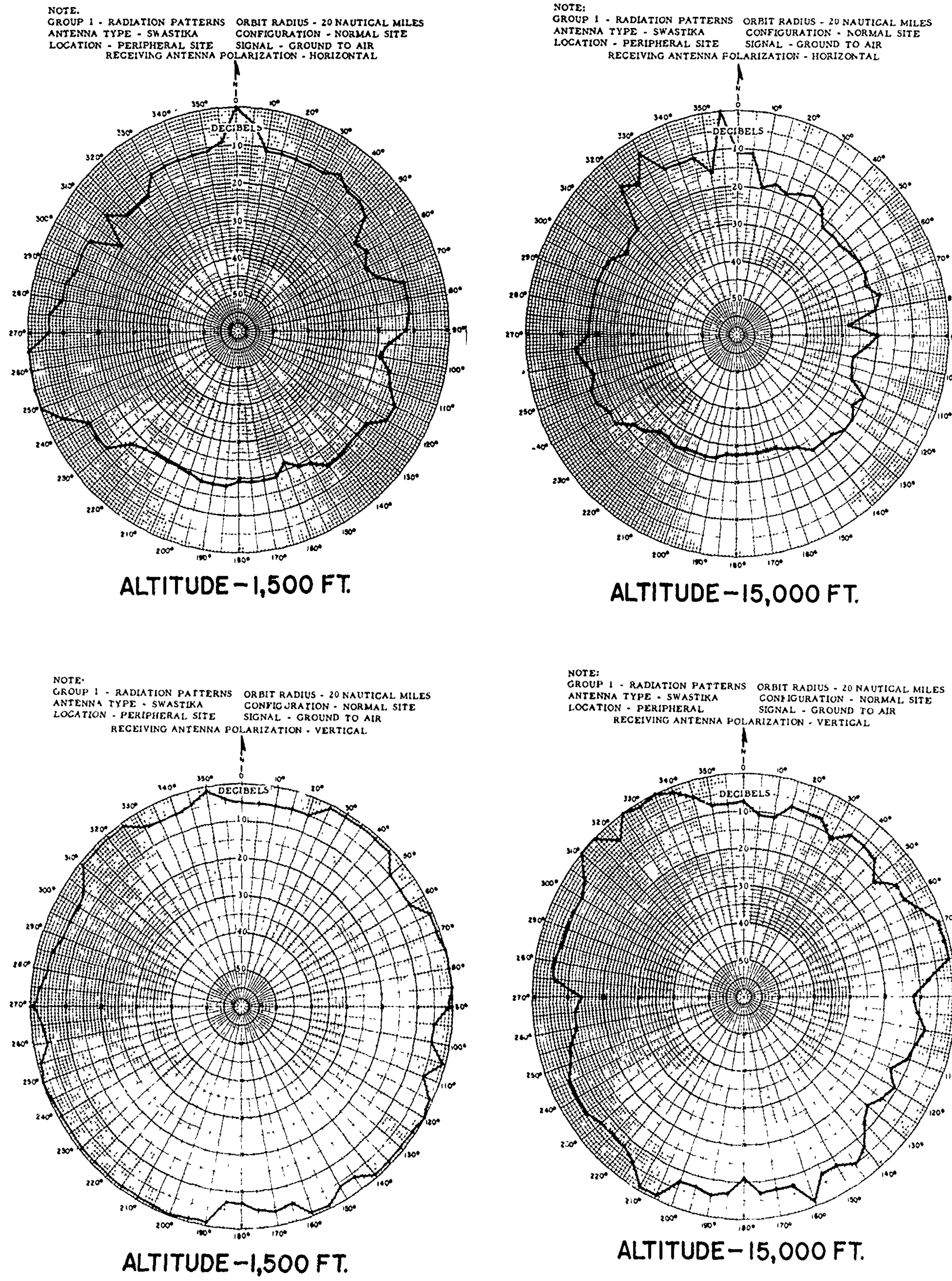
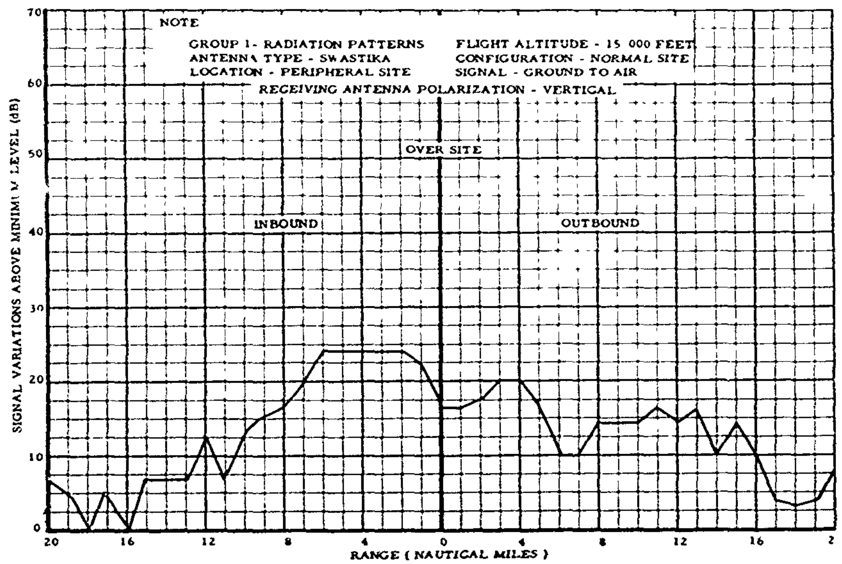
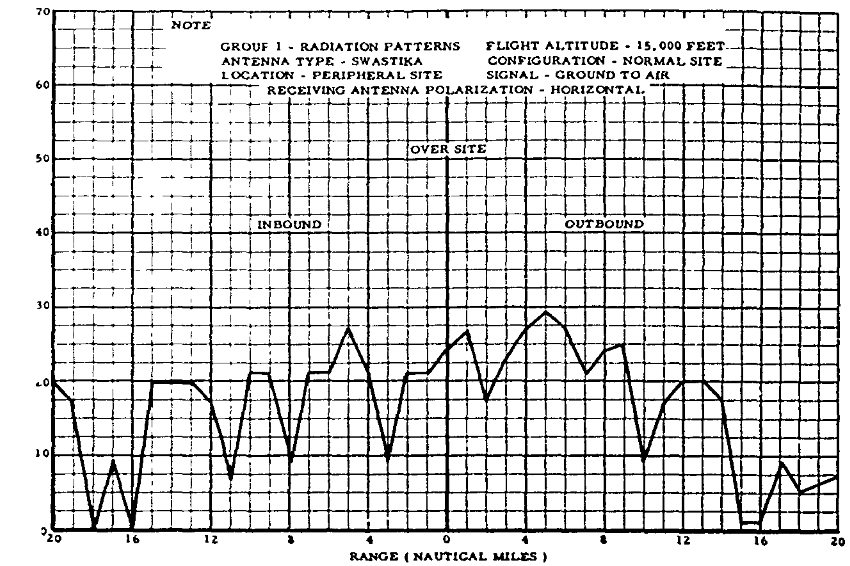


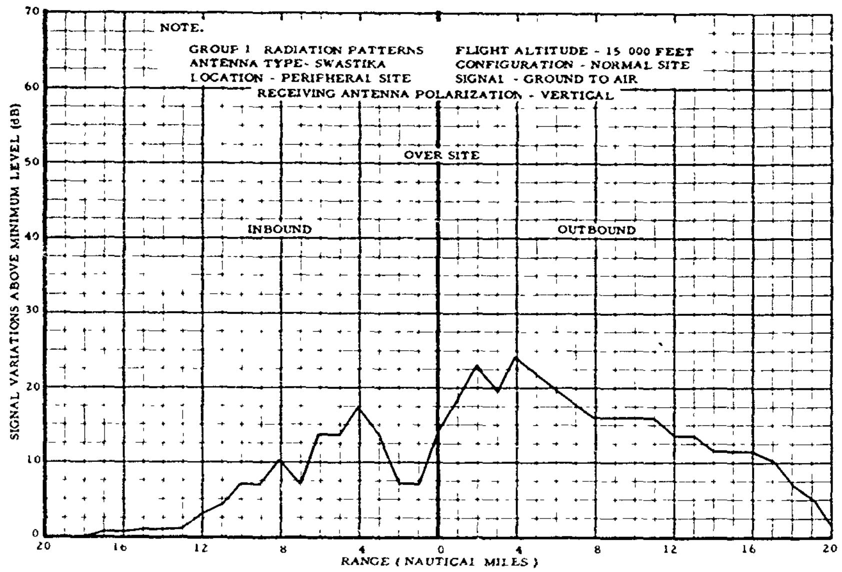
FIG. 22 ORBITAL FLIGHT PATTERN PLOTS SHOWING SIGNAL VARIATIONS ABOVE MINIMUM LEVEL FOR VHF SWASTIKA ANTENNA, NORMAL ANTENNA CONFIGURATION



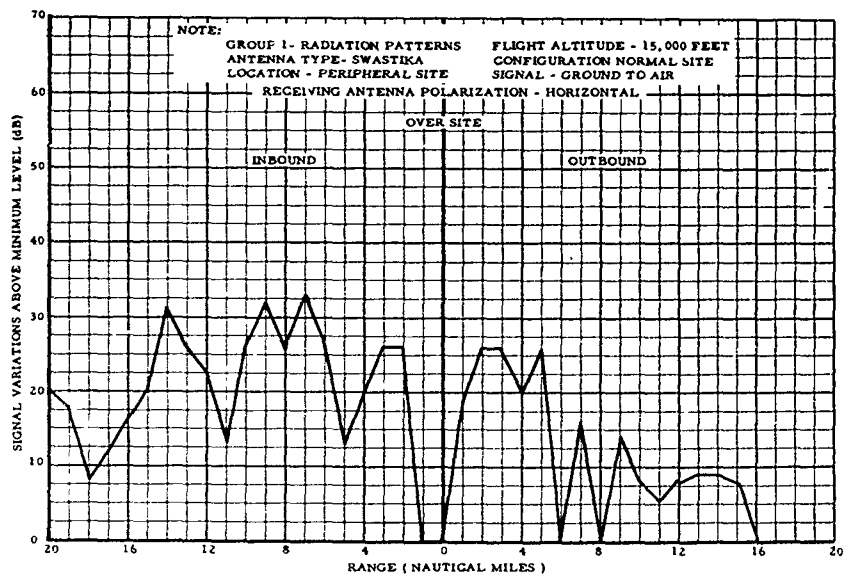
RADIAL N-S



RADIAL N-S



RADIAL E-W



RADIAL E-W

FIG. 23 RADIAL FLIGHT PATTERN PLOTS SHOWING SIGNAL VARIATIONS ABOVE MINIMUM LEVEL FOR VHF SWASTIKA ANTENNA, NORMAL ANTENNA CONFIGURATION

Orbital and radial flights were also accomplished utilizing the swastika antenna with all other antennas removed from the four towers at the test site. Results from these tests are shown in Figures 24 and 25. In the orbital pattern (Figure 24), improvement in the symmetry of the radiation pattern is in evidence at an aircraft altitude of 15, 000 feet for horizontal polarization. The most notable changes in the radial pattern (Figure 25) was some shifting of the points in the inbound and outbound runs at which maximum signal levels occurred.

A similar flight test was performed utilizing the swastika antenna mounted on a wooden pole 12 feet above the antenna tower to determine what degree of improvement in the radiation patterns would be realized by removing the antenna from the proximity of the tower platform. The results of these tests are shown in Figures 26 and 27. For the orbital patterns (Figure 26), improvement in symmetry of the horizontal pattern at an altitude of 15, 000 feet was the most notable change in results as compared with previous tests. The radial patterns (Figure 27) provided data near similar to that with the normal antenna configuration.

B. Type CA-1511 Antenna - Flight tests were performed utilizing the Type CA-1511 VHF coaxial Antenna as the radiating element installed in a normal configuration at the Experimental Peripheral Communications Facility. Results of these tests are shown in Figures 28 and 29. For orbital patterns (Figure 28), good symmetry in coverage is in evidence for only vertical polarized signals as received at the airborne terminal. Horizontally polarized signals are concentrated in particular areas as indicated by the pattern lobes. For the radial patterns (Figure 29), maximum levels of horizontally polarized signals occurred at distances of 4 nmi with the aircraft proceeding outbound in the north to south direction, and at 6 and 2 nmi inbound, and from 3 to 5 nmi outbound, when proceeding in the east to west direction. For vertically polarized signals, the maximum signal levels occurred at approximately 3 nmi outbound, north to south direction, and 2 nmi inbound and from 3 to 4 nmi outbound when proceeding in the east to west direction.

Comparative tests were performed at the NAFEC DARTS site utilizing both the CA-1781 Swastika and CA-1511 Coaxial Antennas. It should be noted that this particular site was free from obstructions and reflecting surfaces out to a distance of 2500 feet. One phase of these tests involved the swastika antenna as a radiating element mounted on a

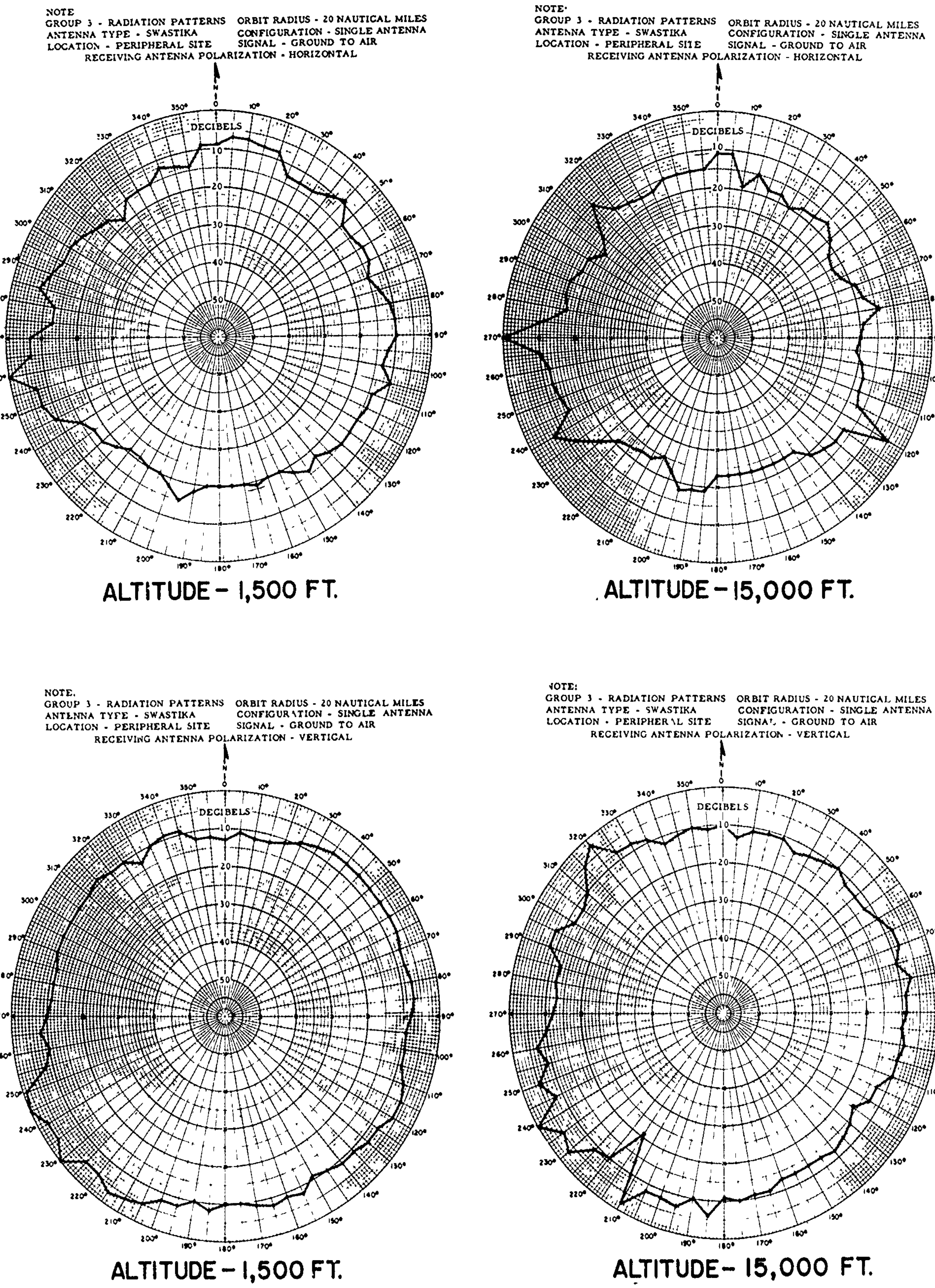
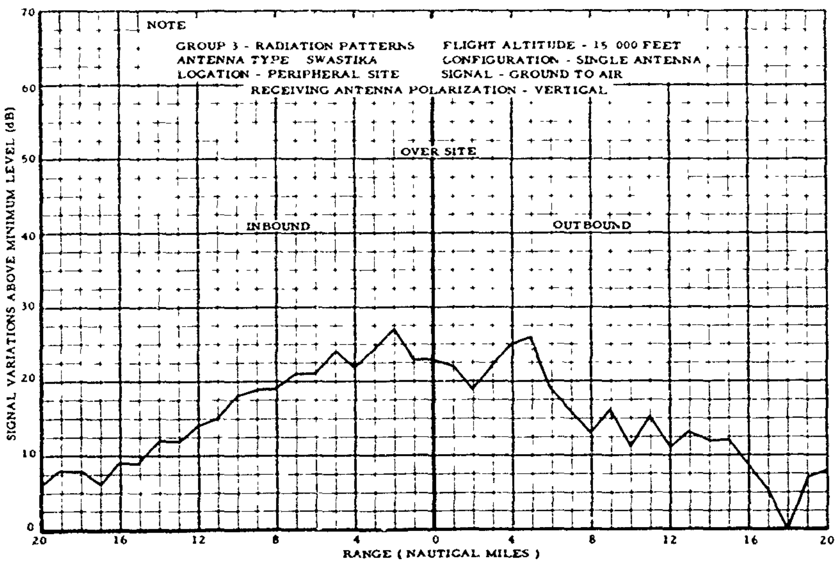
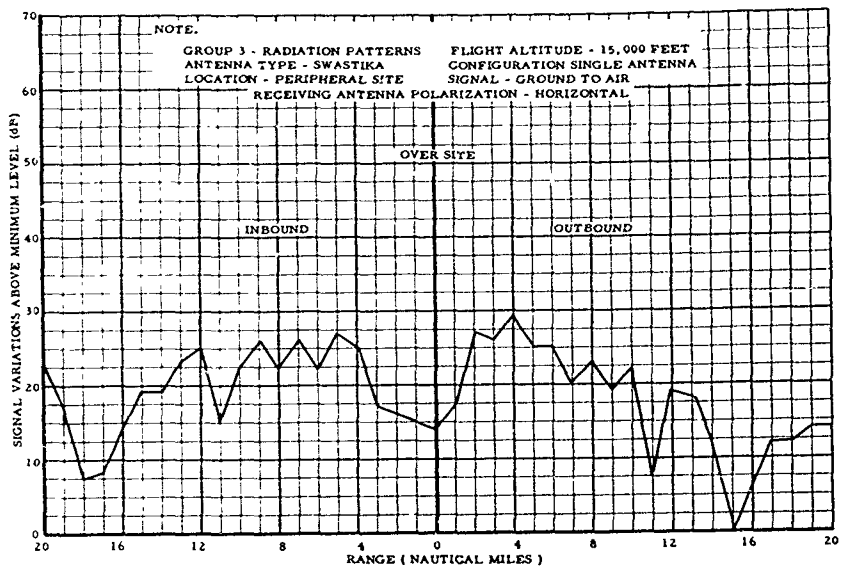


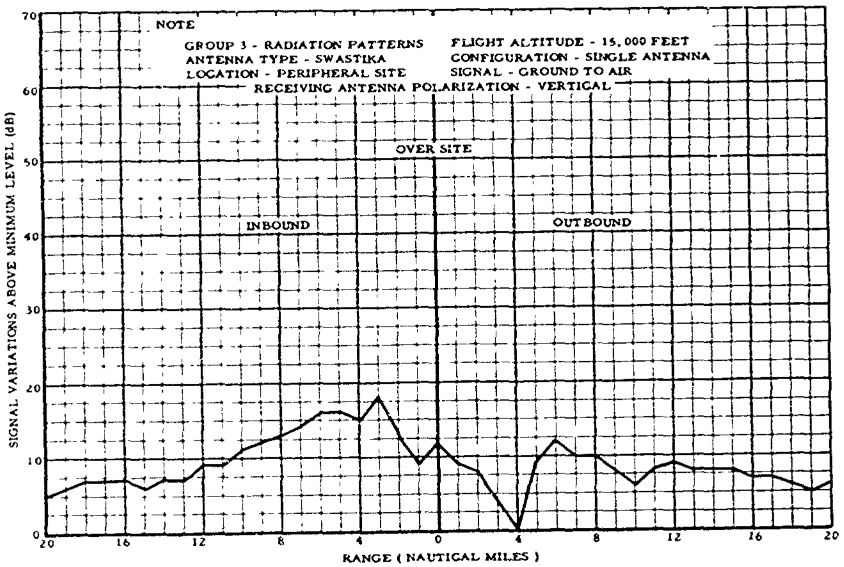
FIG. 24 ORBITAL FLIGHT PATTERN PLOTS SHOWING SIGNAL VARIATIONS ABOVE MINIMUM LEVEL FOR VHF SWASTIKA ANTENNA, SINGLE ANTENNA CONFIGURATION



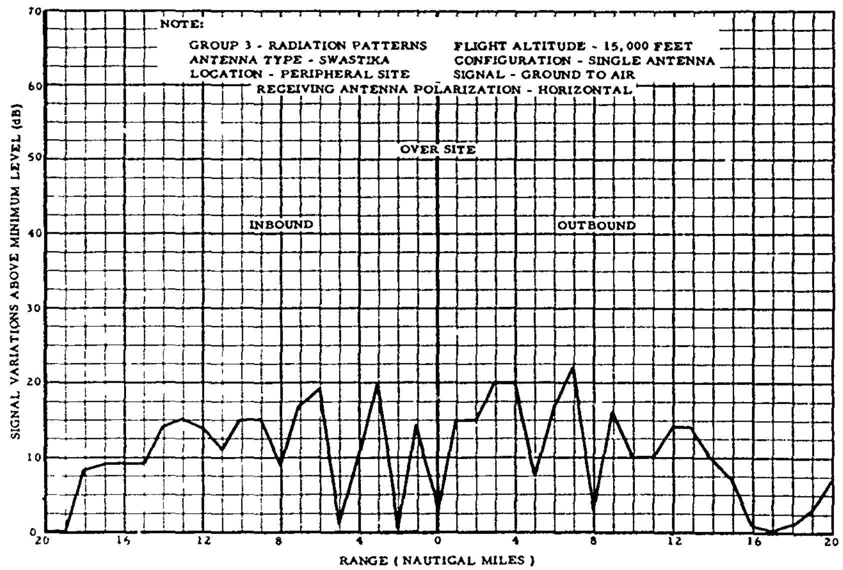
RADIAL N–S



RADIAL N–S



RADIAL E–W



RADIAL E–W

FIG. 25 RADIAL FLIGHT PATTERN PLOTS SHOWING SIGNAL VARIATIONS ABOVE MINIMUM LEVEL FOR VHF SWASTIKA ANTENNA, SINGLE ANTENNA CONFIGURATION

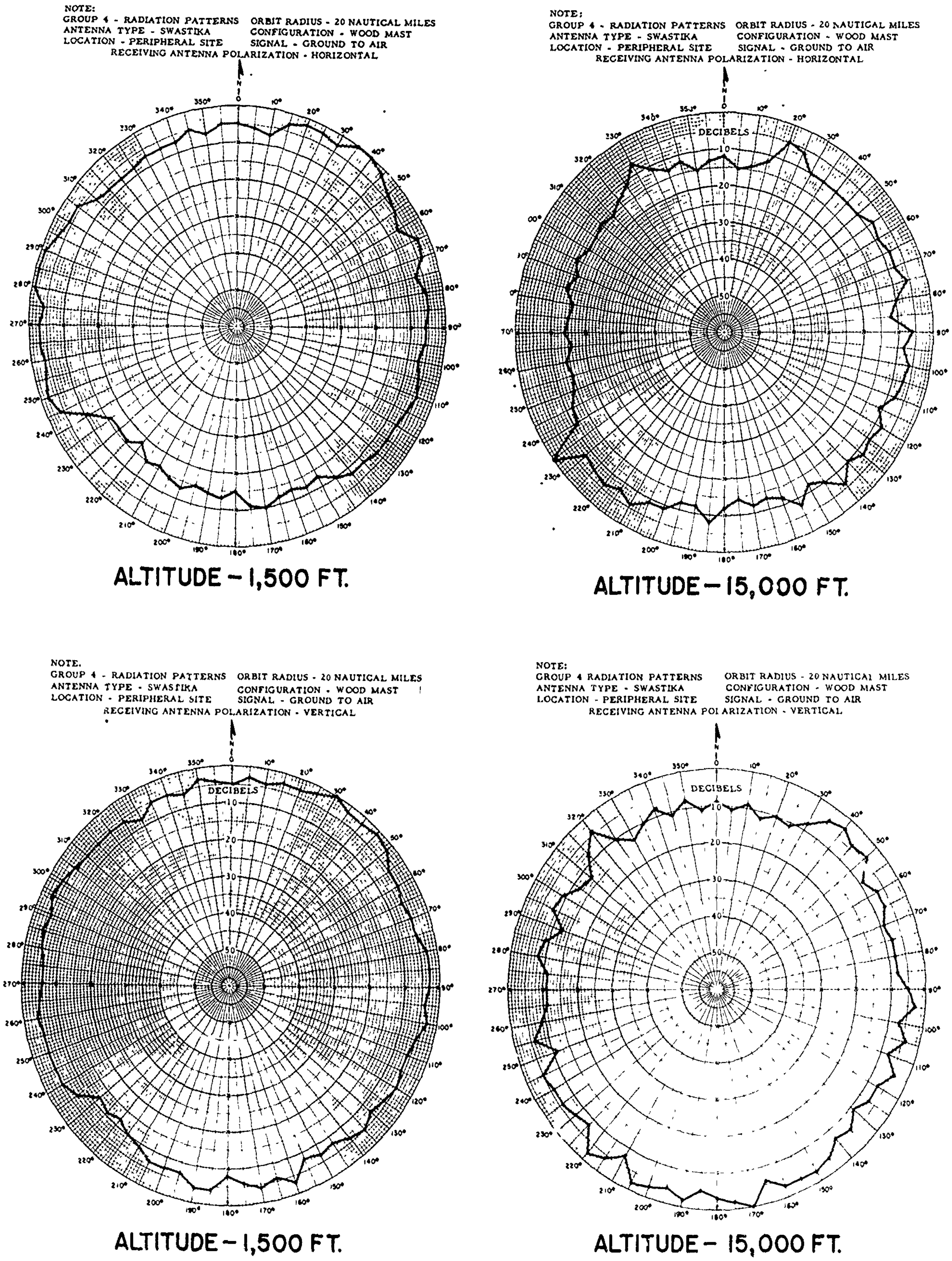
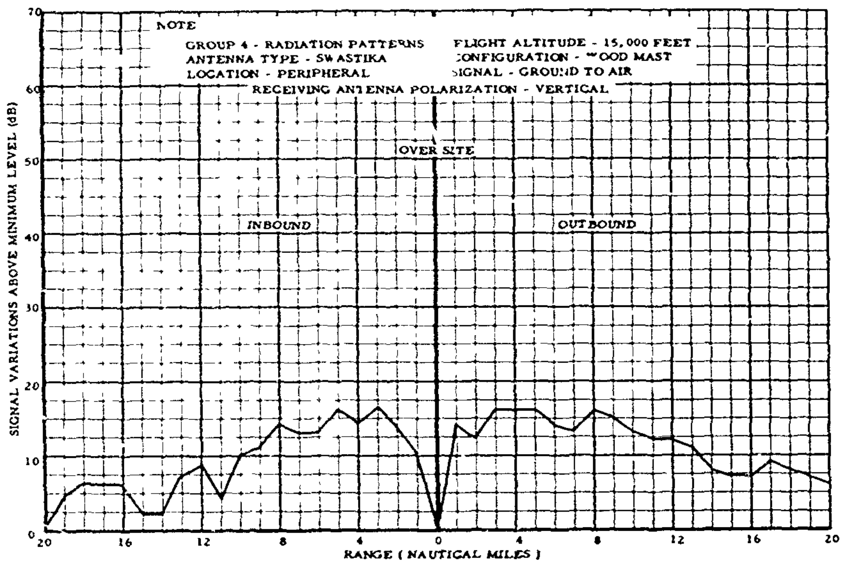
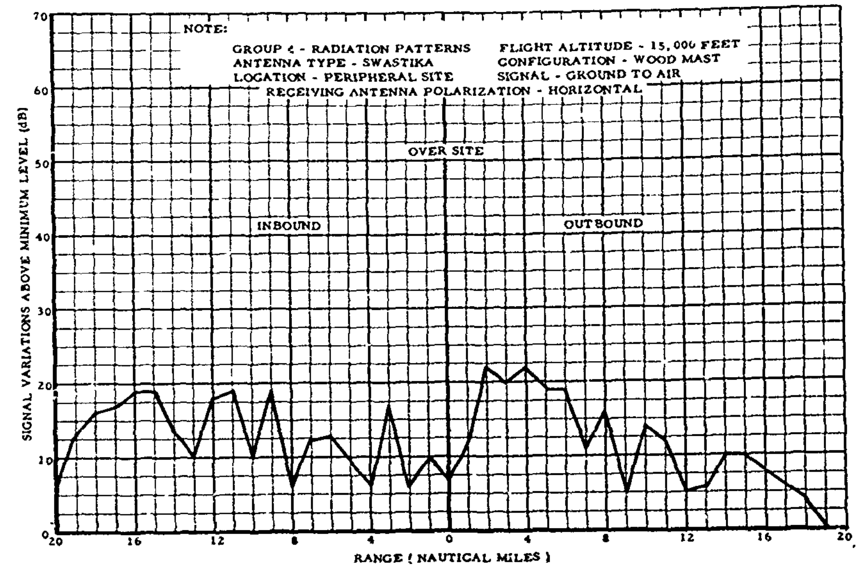


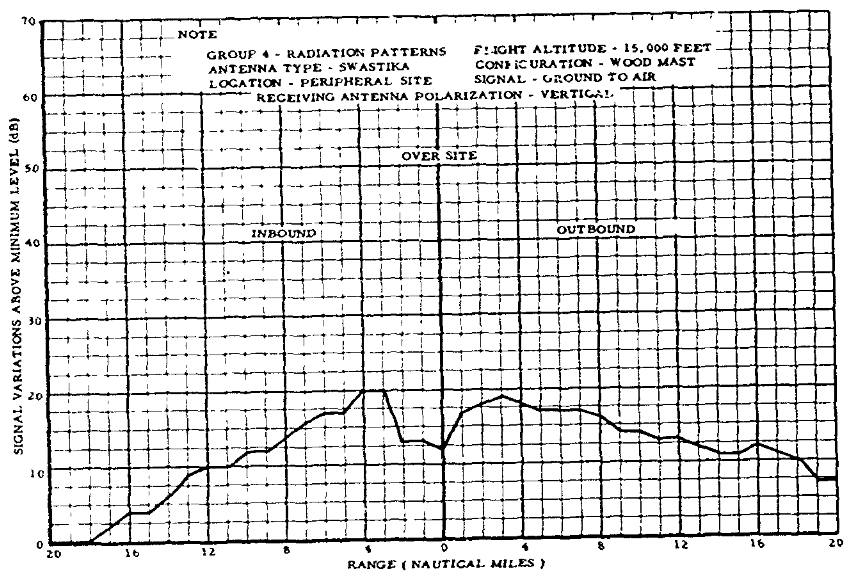
FIG. 26 ORBITAL FLIGHT PATTERN PLOTS SHOWING SIGNAL VARIATIONS ABOVE MINIMUM LEVEL FOR VHF SWASTIKA ANTENNA, WOOD MAST CONFIGURATION



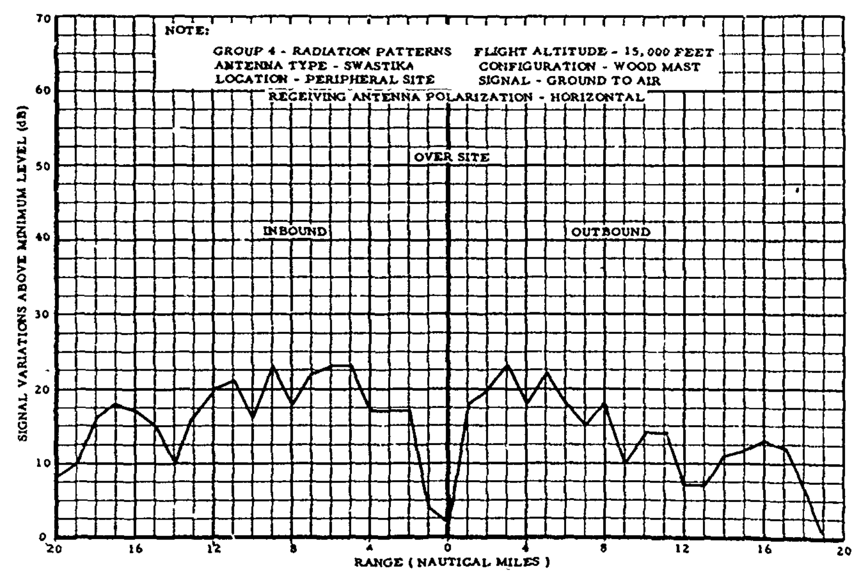
RADIAL N-S



RADIAL N-S



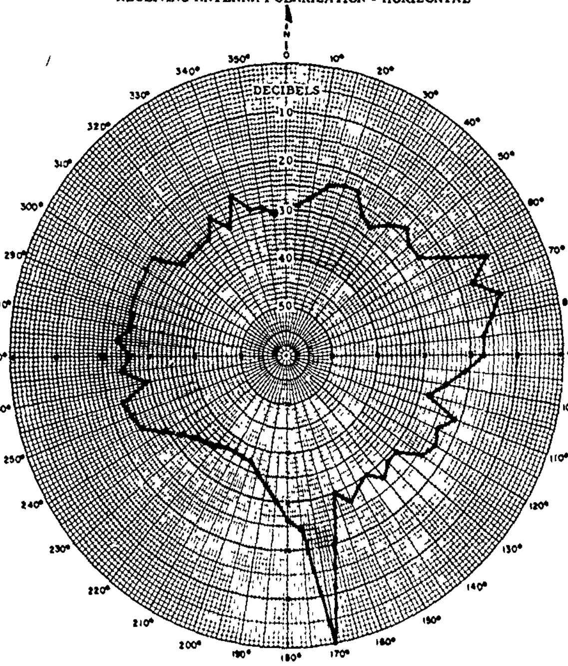
RADIAL E-W



RADIAL E-W

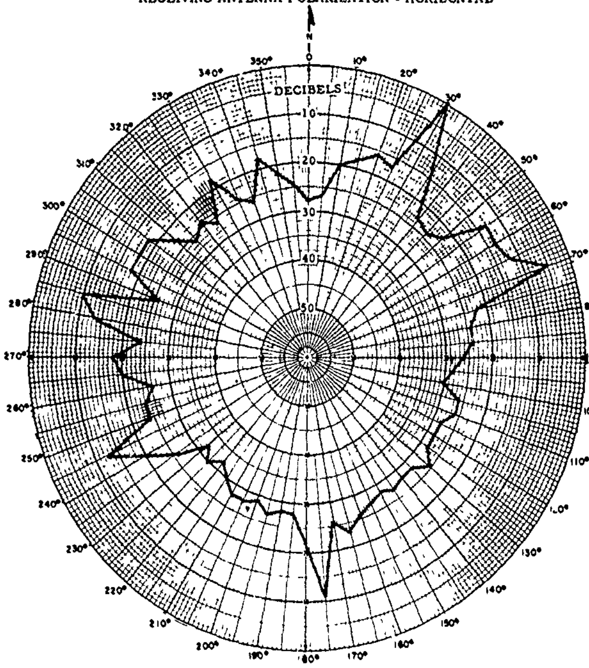
FIG. 27 RADIAL FLIGHT PATTERN PLOTS SHOWING SIGNAL VARIATIONS ABOVE MINIMUM LEVEL FOR VHF SWASTIKA ANTENNA, WOOD MAST CONFIGURATION

NOTE:
GROUP 2 - RADIATION PATTERNS ORBIT RADIUS - 20 NAUTICAL MILES
ANTENNA TYPE - COAXIAL CONFIGURATION - NORMAL SITE
LOCATION - PERIPHERAL SITE SIGNAL - GROUND TO AIR
RECEIVING ANTENNA POLARIZATION - HORIZONTAL



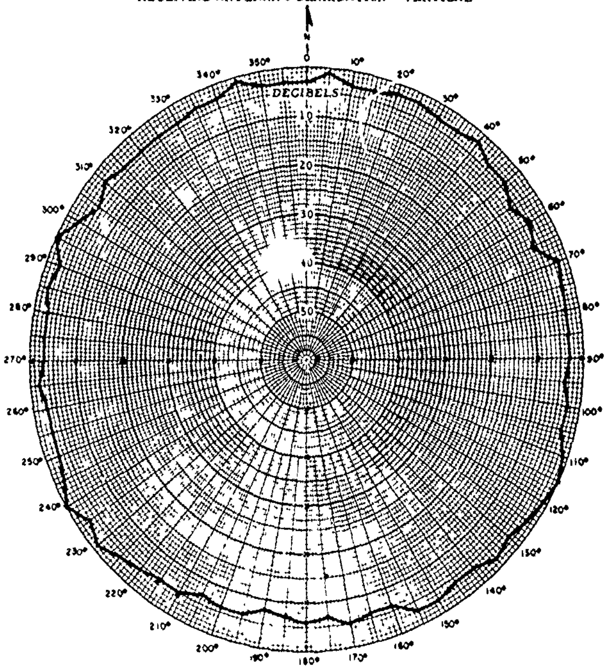
ALTITUDE-1,500 FT.

NOTE:
GROUP 2 - RADIATION PATTERNS ORBIT RADIUS - 20 NAUTICAL MILES
ANTENNA TYPE - COAXIAL CONFIGURATION - NORMAL SITE
LOCATION - PERIPHERAL SITE SIGNAL - GROUND TO AIR
RECEIVING ANTENNA POLARIZATION - HORIZONTAL



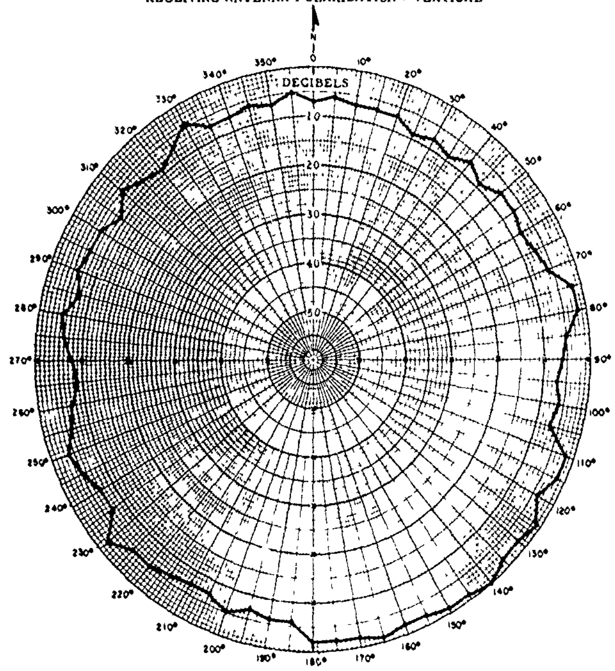
ALTITUDE-15,000 FT.

NOTE.
GROUP 2 - RADIATION PATTERNS ORBIT RADIUS - 20 NAUTICAL MILES
ANTENNA TYPE - COAXIAL CONFIGURATION - NORMAL SITE
LOCATION - PERIPHERAL SITE SIGNAL - GROUND TO AIR
RECEIVING ANTENNA POLARIZATION - VERTICAL



ALTITUDE-1,500 FT.

NOTE:
GROUP 2 - RADIATION PATTERNS ORBIT RADIUS - 20 NAUTICAL MILES
ANTENNA TYPE - COAXIAL CONFIGURATION - NORMAL SITE
LOCATION - PERIPHERAL SITE SIGNAL - GROUND TO AIR
RECEIVING ANTENNA POLARIZATION - VERTICAL



ALTITUDE-15,000 FT.

FIG. 28 ORBITAL FLIGHT PATTERN PLOTS SHOWING SIGNAL VARIATIONS ABOVE MINIMUM LEVEL FOR VHF COAXIAL ANTENNA, NORMAL ANTENNA CONFIGURATION

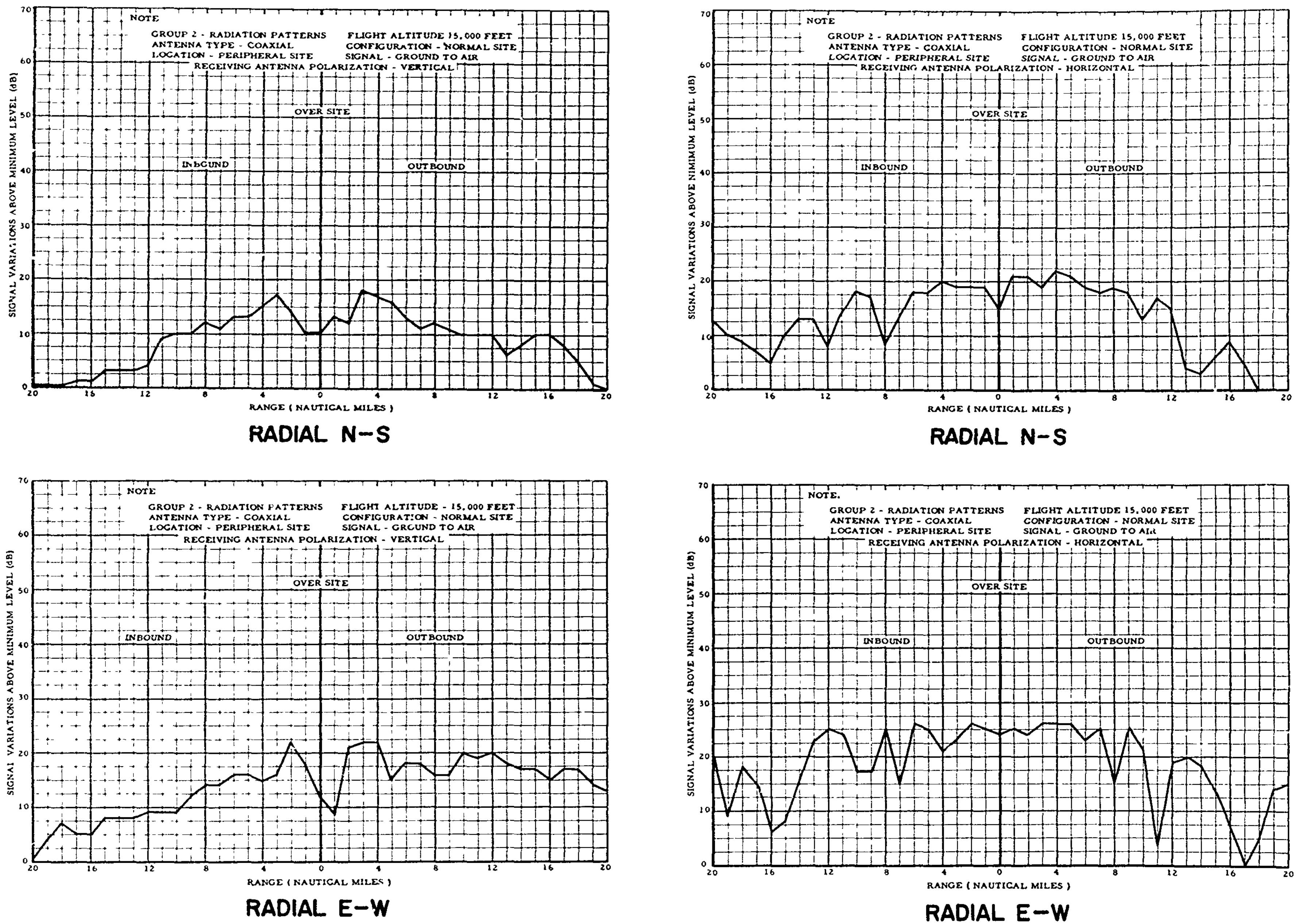


FIG. 29 RADIAL FLIGHT PATTERN PLOTS SHOWING SIGNAL VARIATIONS ABOVE MINIMUM LEVEL FOR VHF COAXIAL ANTENNA, NORMAL ANTENNA CONFIGURATION

wooden pole and positioned 12 feet above the ground. Orbital and radial patterns were obtained using procedures similar to that described for tests at the Peripheral Communications Site, with the aircraft utilizing horizontally and vertically polarized antennas. A second phase of the tests at the DARTS Site involved both the coaxial and swastika antennas as receiving elements mounted on wooden poles 12 feet above the ground as depicted in Figure 30. These latter tests consisted of radial patterns only, and were made at an altitude of 1500 feet, with the aircraft utilizing a vertically polarized antenna.

Results of the test with the aircraft utilizing its horizontally polarized antenna are presented in Figure 31, and the results of vertically polarized antenna on the aircraft are presented in Figure 32. The most apparent influence of the DARTS Site on the orbital pattern with respect to improvement in symmetry was for horizontal polarization. In the radial patterns, with the swastika and coaxial antenna receiving vertically polarized signals from the aircraft, the coaxial antenna communication range was greater than the swastika antenna as shown in Figure 33.

C. Type AT-197, FA-5676X and 437B-1 Antennas - Radiation patterns were obtained for a flight level of 2500 feet on radials of 30° to 210°, and 240° to 60° utilizing the UHF AT-197, Scanwell 5676X, and Collins 437B-1 Antennas installed on the west tower at the Experimental Peripheral Communications Facility. Each antenna was tested separately. A second AT-197, was mounted on the north tower at the site and used as a reference in each test. RF transmissions were made from the aircraft on a frequency of 300.1 MHz utilizing an AT-256 Antenna. All radiation patterns were acquired the same day to minimize variables due to weather. The Collins 437B-1 Antenna, obtained on loan for minimal evaluation, is shown in Figure 34.

Results of these tests are shown in Figures 35 through 40. The radiation patterns of the antennas under test correlated well with the reference antenna patterns. The Scanwell 5676X Antenna exhibited relative smooth patterns with minimum nulls. It should be noted that the discontinuity in the data for the outbound radial (Figure 38) was due to temporary equipment failure. The data comprising the radiation patterns of Figure 39 was obtained from two different flights, subsequently, the flight paths were slightly different. This difference is reflected in the plot of the received signal level as the aircraft was positioned over the test site on the inbound radial.

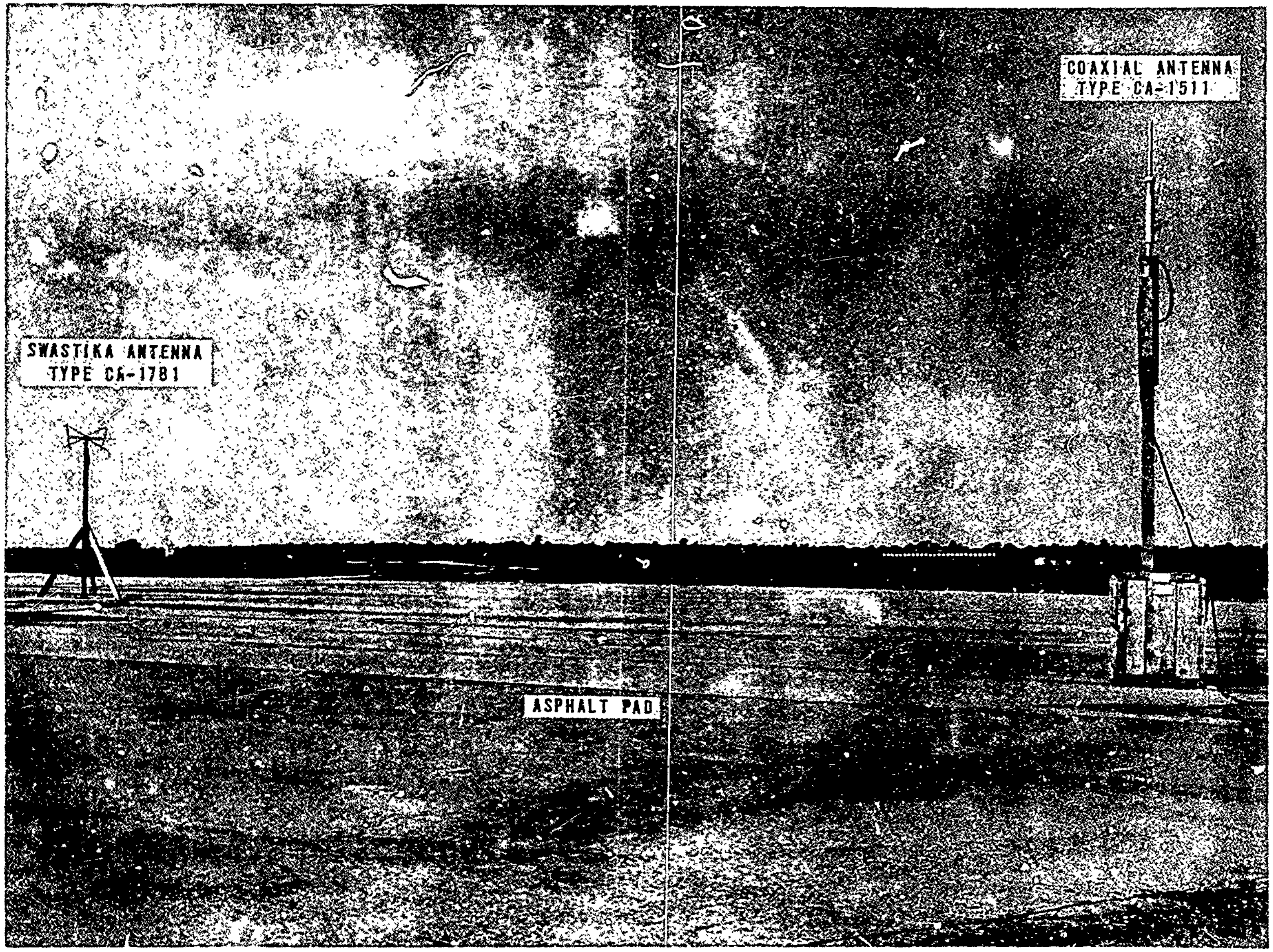
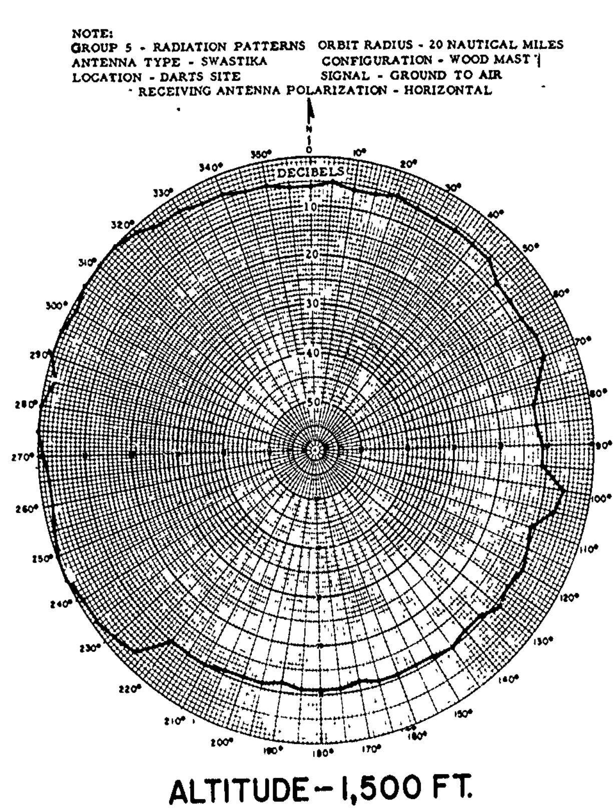
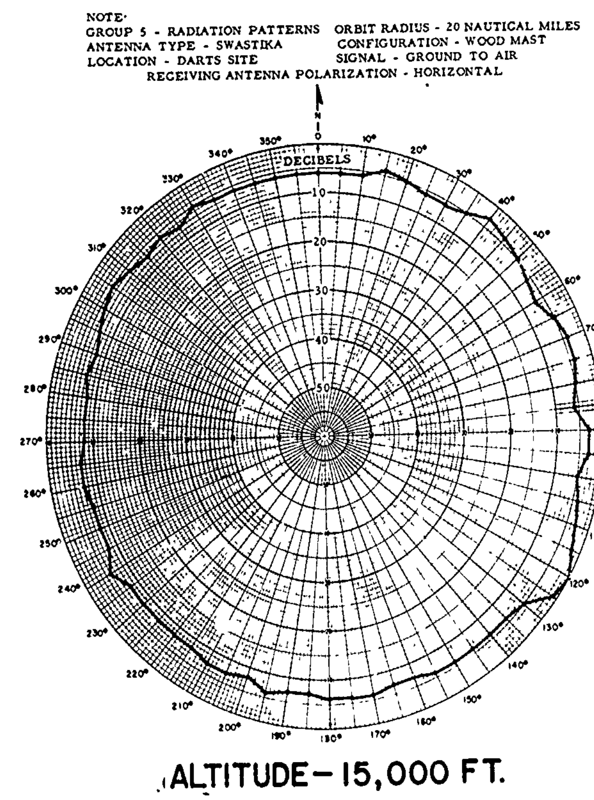
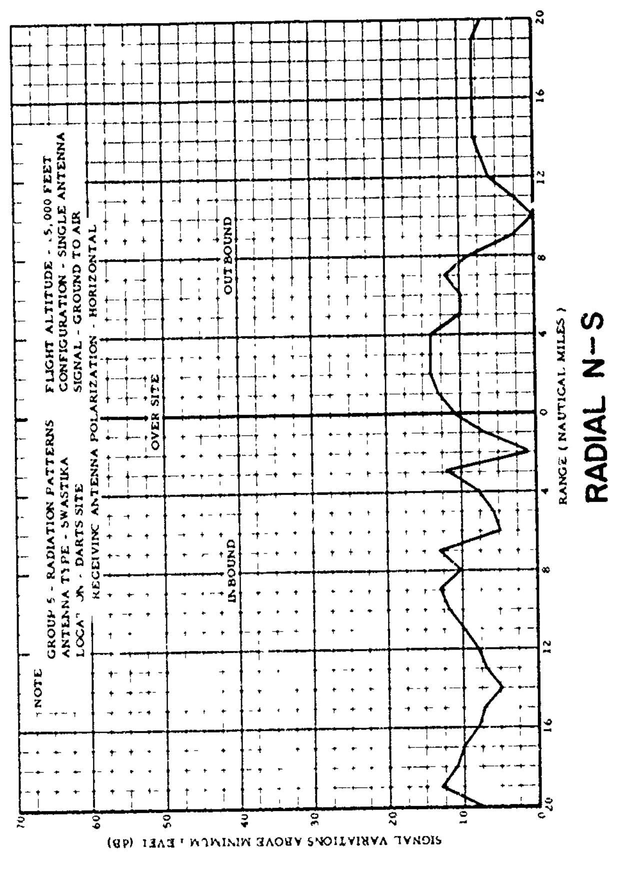


FIG. 30 VHF SWASTIKA AND COAXIAL ANTENNAS INSTALLED ON WOOD MASTS AT THE DARTS SITE







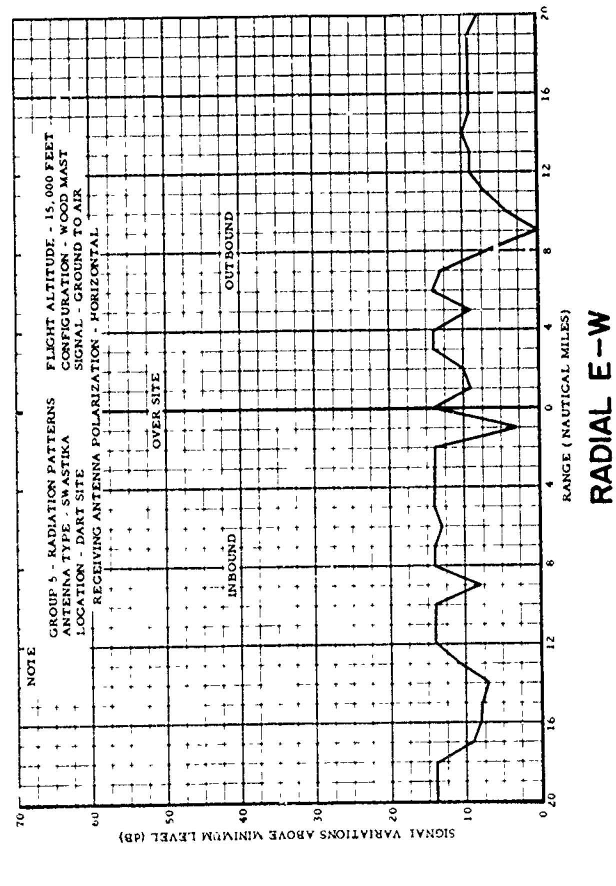
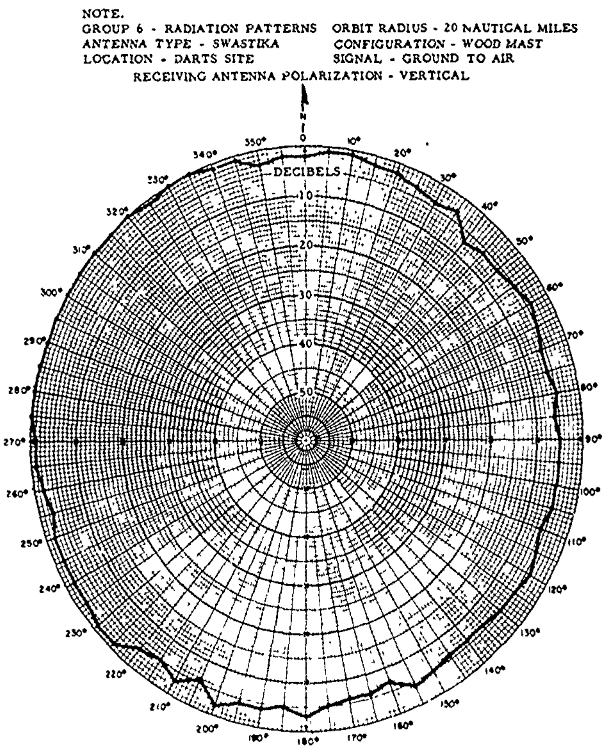
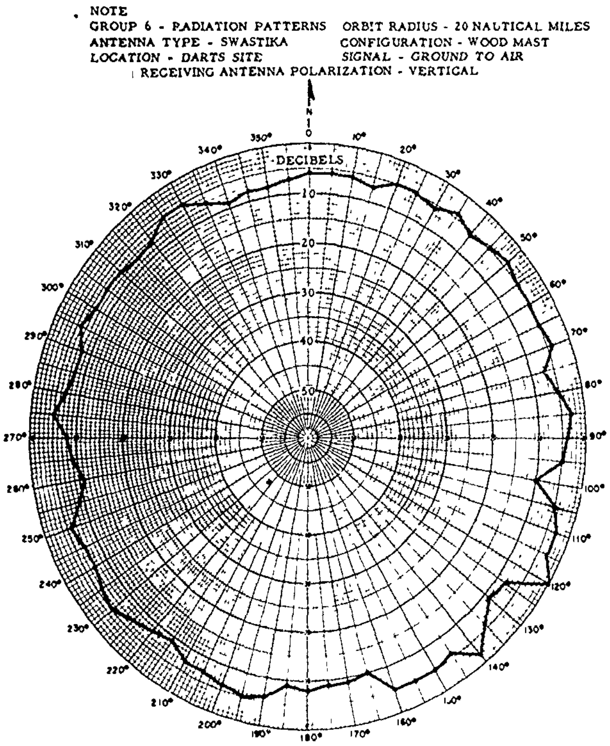


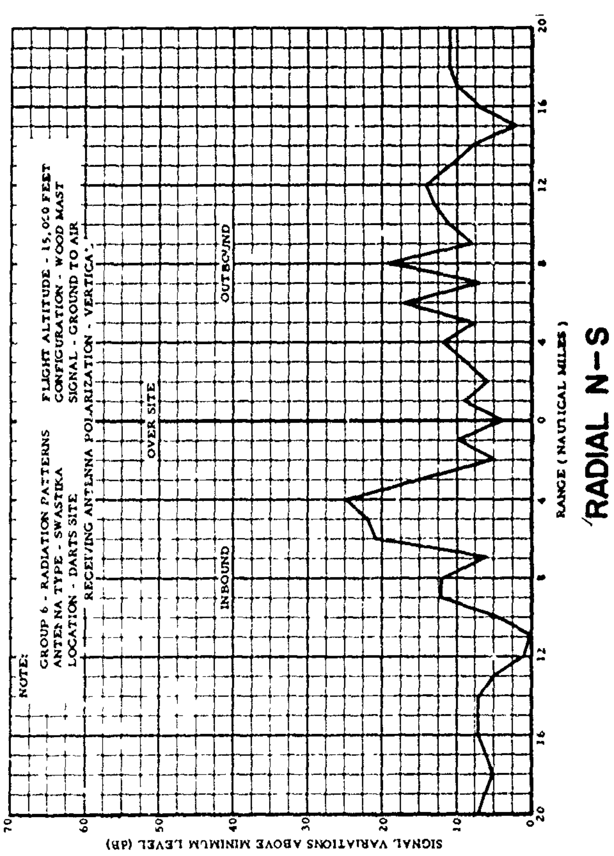
FIG. 31 ORBITAL AND RADIAL FLIGHT PATTERN PLOTS SHOWING SIGNAL VARIATIONS ABOVE MINIMUM LEVEL RECEIVED AT THE AIRBORNE TERMINAL USING A HORIZONTAL POLARIZED ANTENNA



ALTITUDE - 1.500 FT.



ALTITUDE - 15,000 FT.



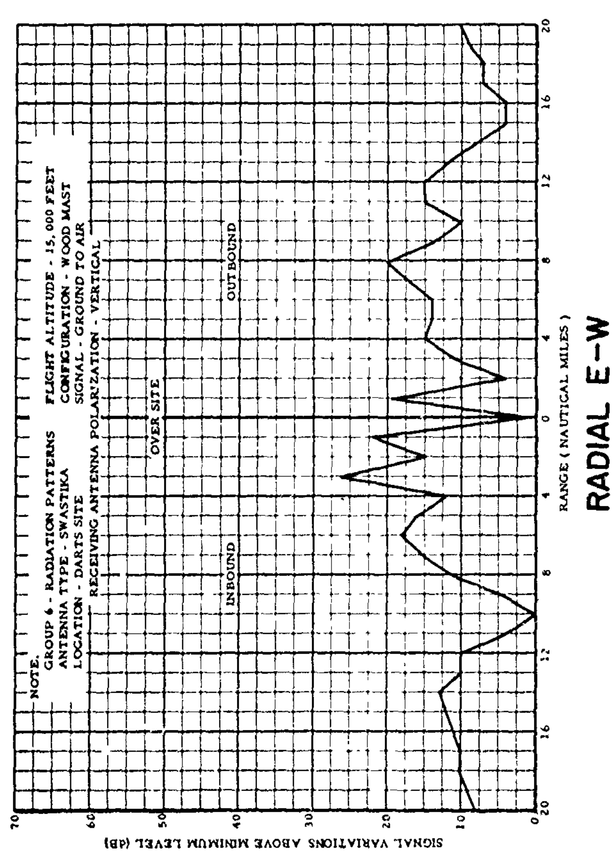


FIG. 32 ORBITAL AND RADIAL FLIGHT PATTERN PLOTS SHOWING SIGNAL VARIATIONS ABOVE MINIMUM LEVEL RECEIVED AT THE AIRBORNE TERMINAL USING A VERTICAL POLARIZED ANTENNA

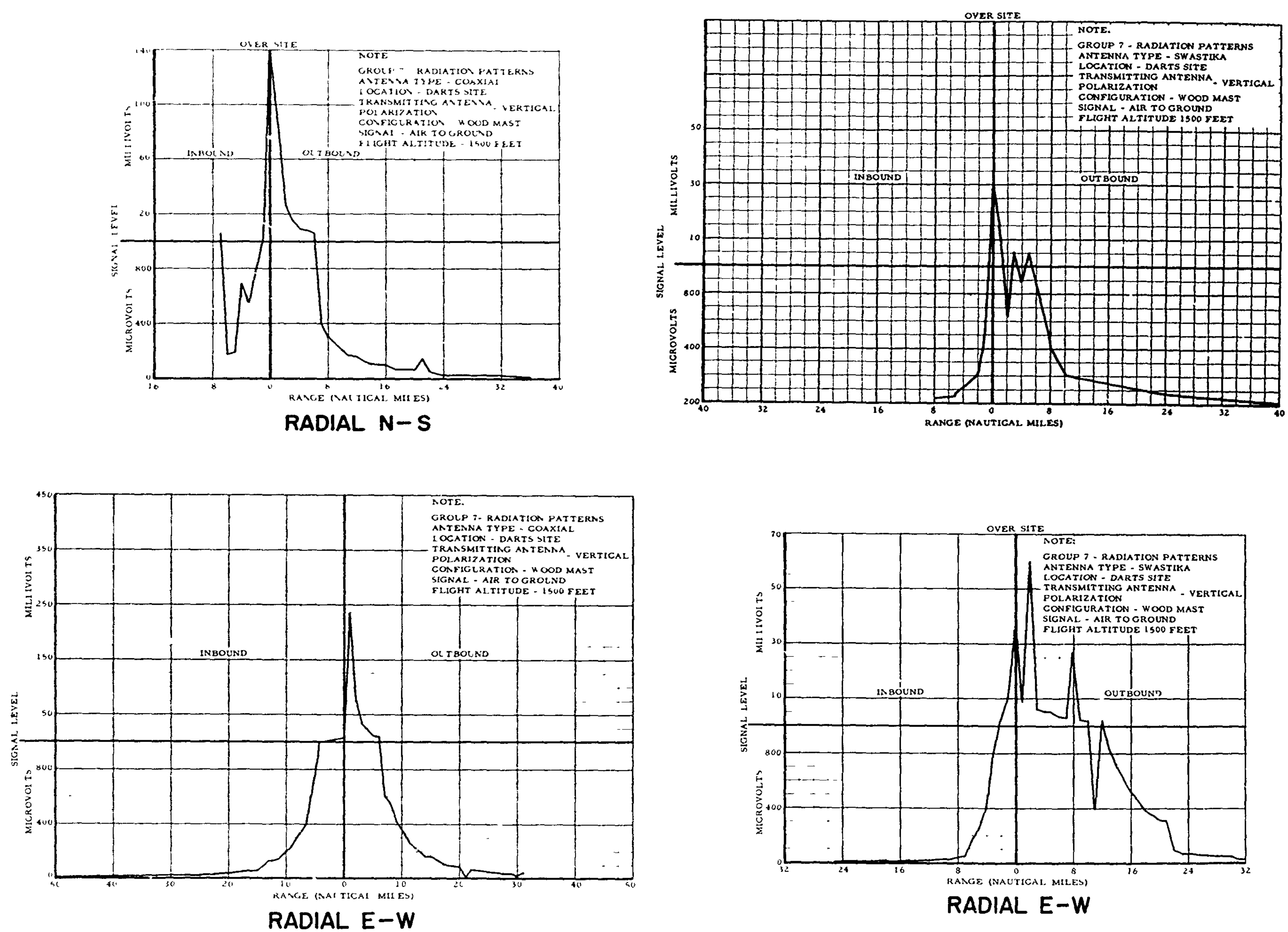


FIG. 33 RADIAL FLIGHT PATTERN PLOTS SHOWING COMPARISON OF SIGNAL VARIATIONS ABOVE MINIMUM LEVEL FOR VHF COAXIAL AND SWASTIKA ANTENNAS INSTALLED AT THE DARTS SITE

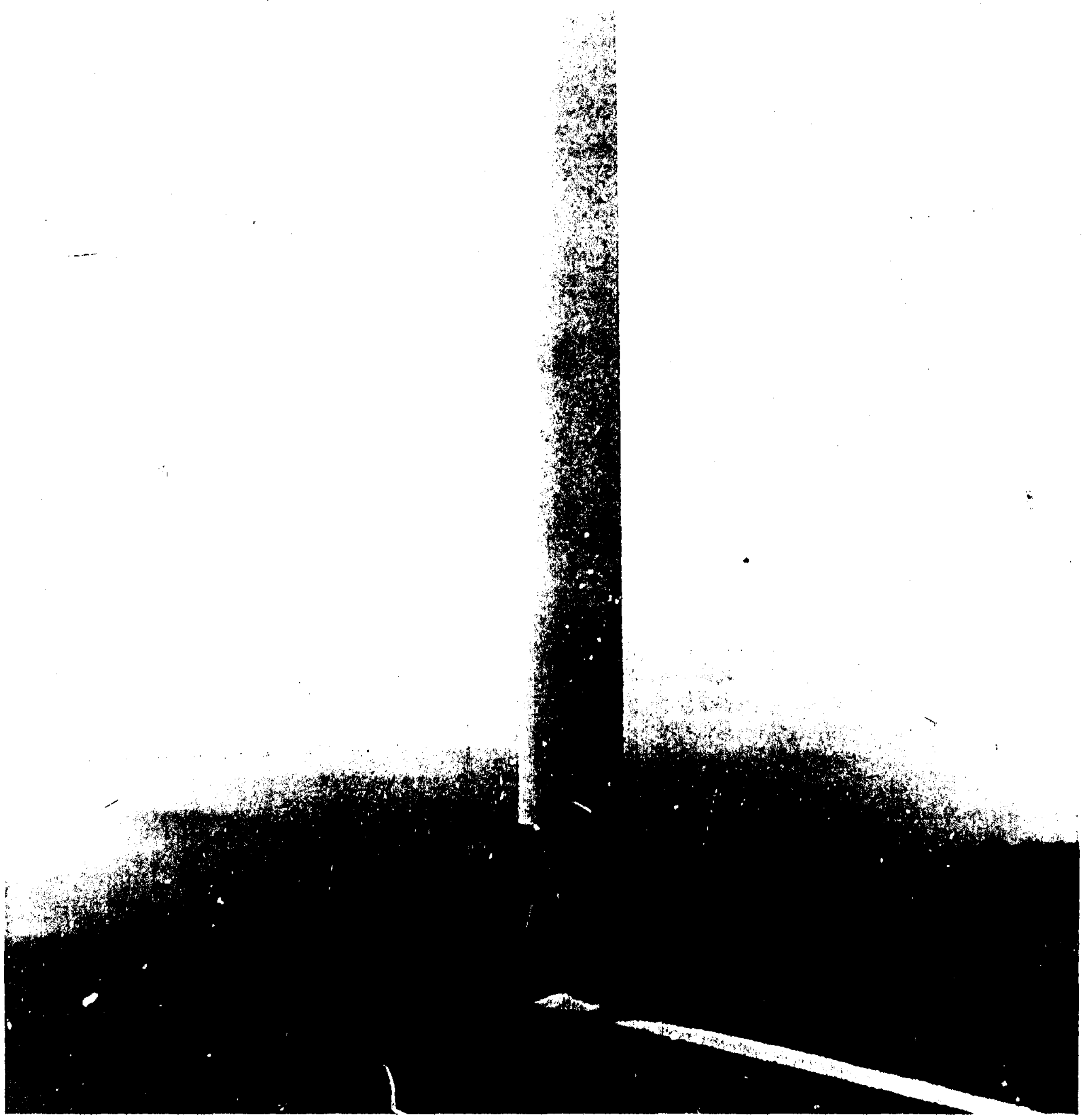


FIG. 34 UHF ANTENNA COLLINS TYPE 437B-1

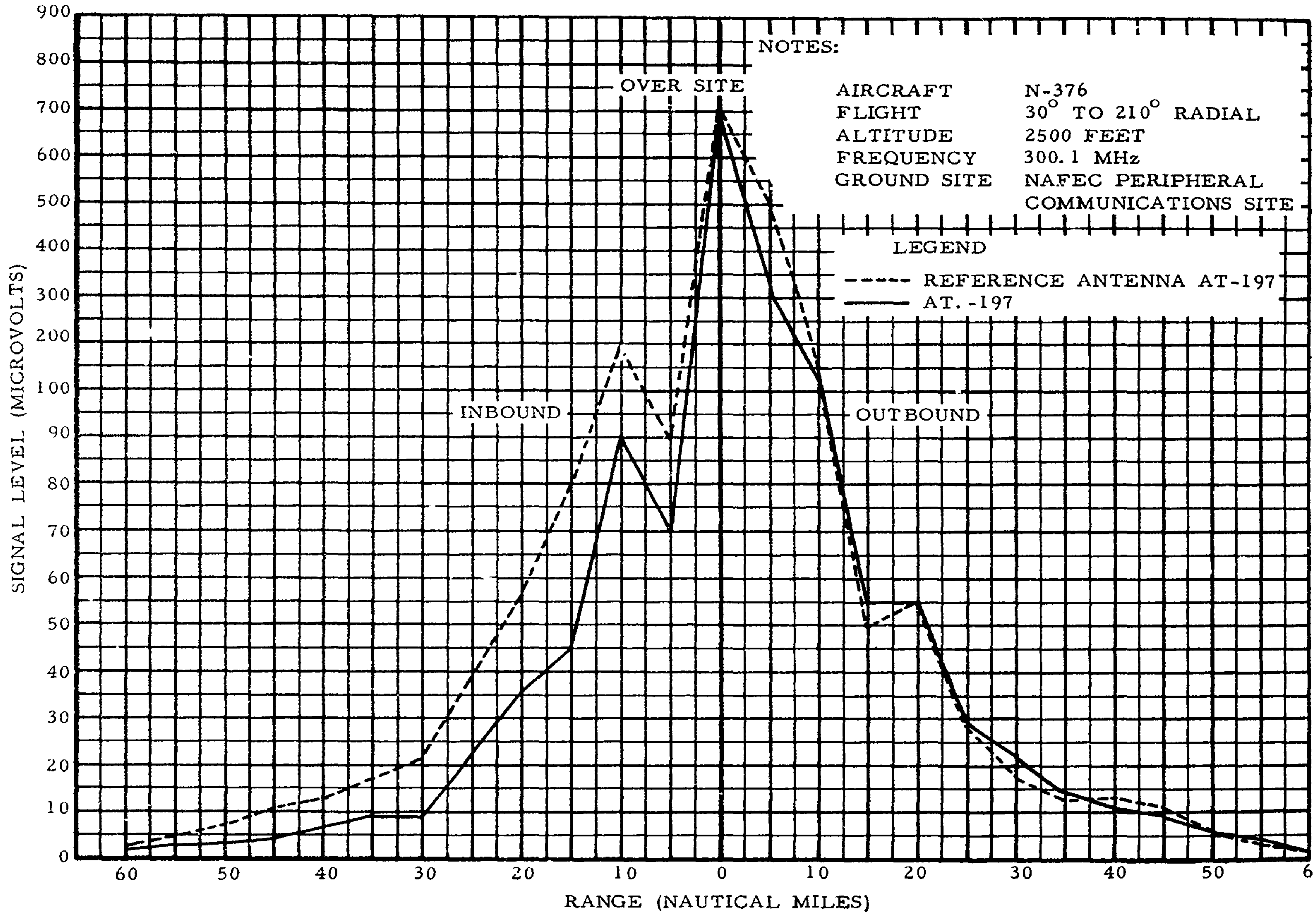


FIG. 35 RADIAL FLIGHT PATTERN OF UHF TYPE AT-197 ANTENNA (30° TO 210° RADIAL)

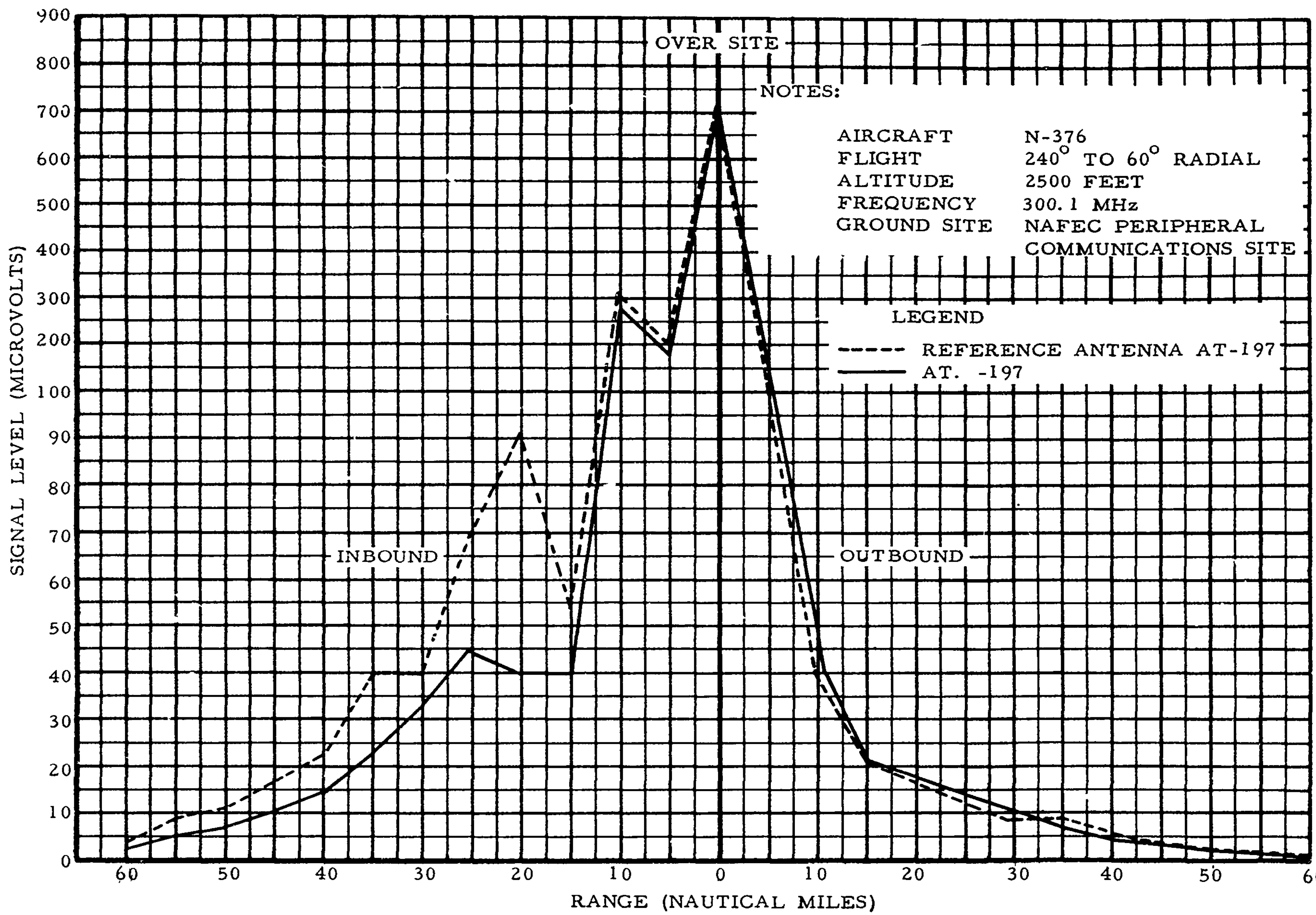


FIG. 36 RADIAL FLIGHT PATTERN OF UHF TYPE AT-197 ANTENNA
(240° TO 60° RADIAL)

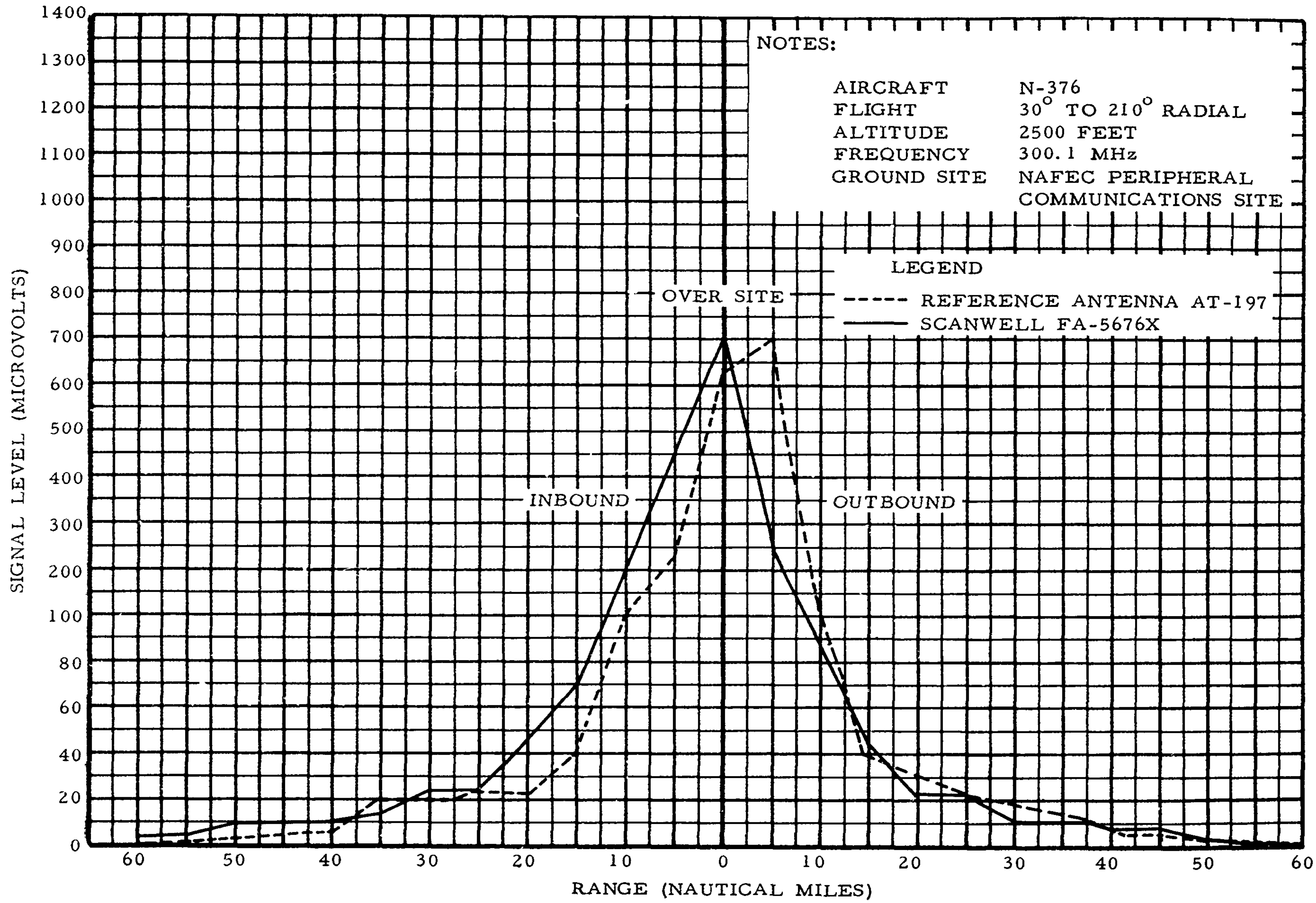


FIG. 37 RADIAL FLIGHT PATTERN OF UHF TYPE FA-5676X ANTENNA (30° TO 210° RADIAL)

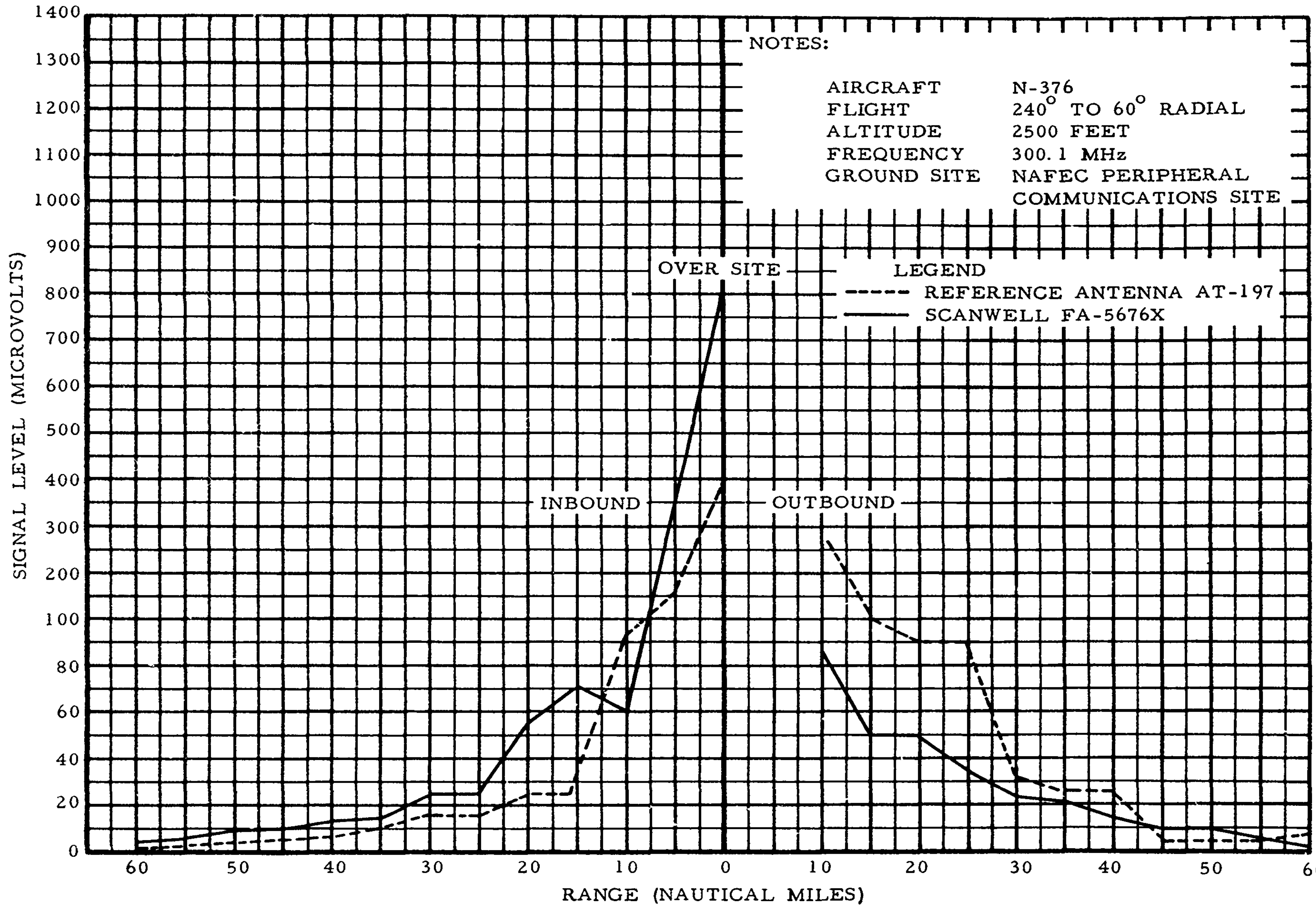


FIG. 38 RADIAL FLIGHT PATTERN OF UHF TYPE FA-5676X ANTENNA (240° TO 60° RADIAL)

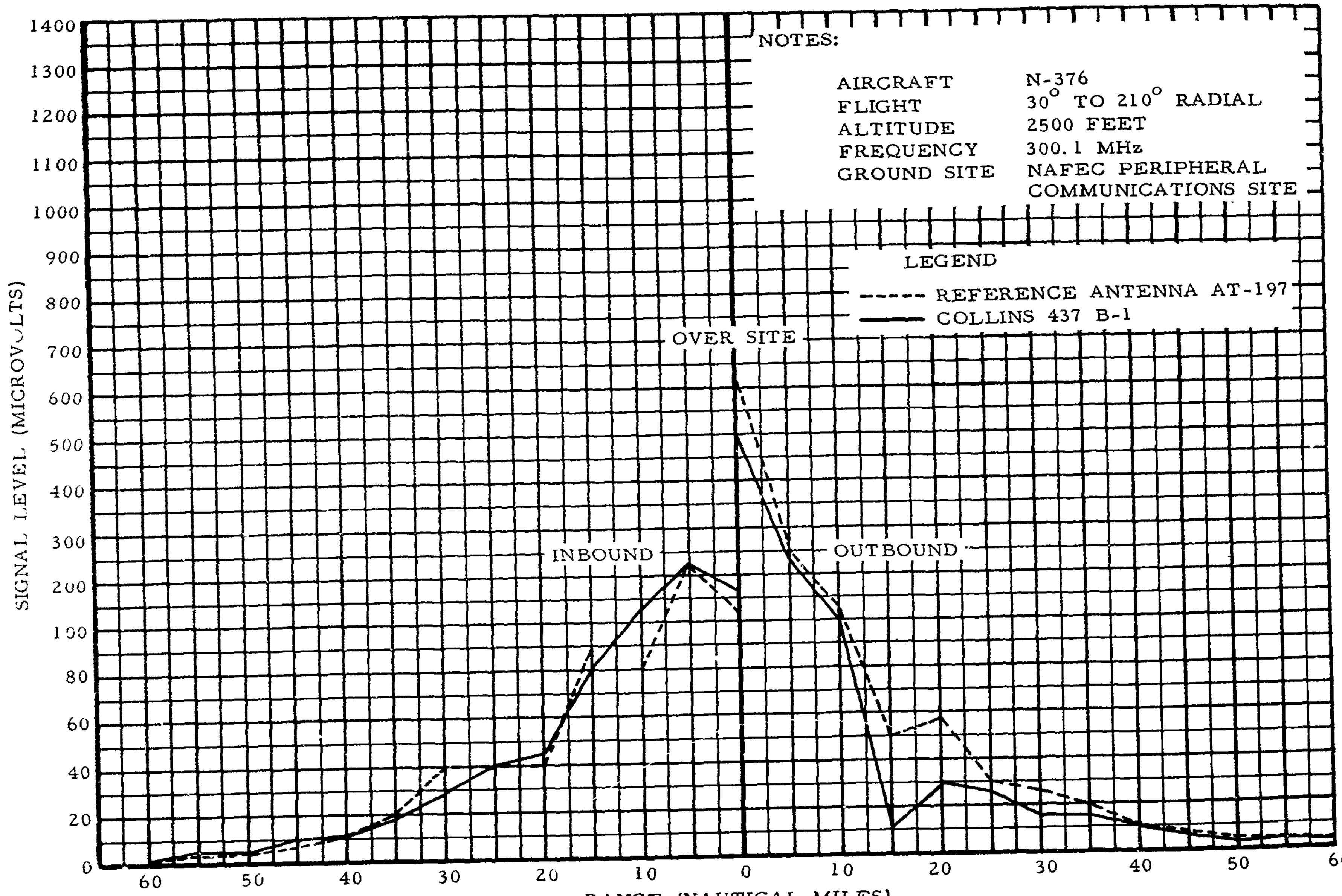


FIG. 39 RADIAL FLIGHT PATTERN OF UHF TYPE 437B-1 ANTENNA (30° TO 210° RADIAL)

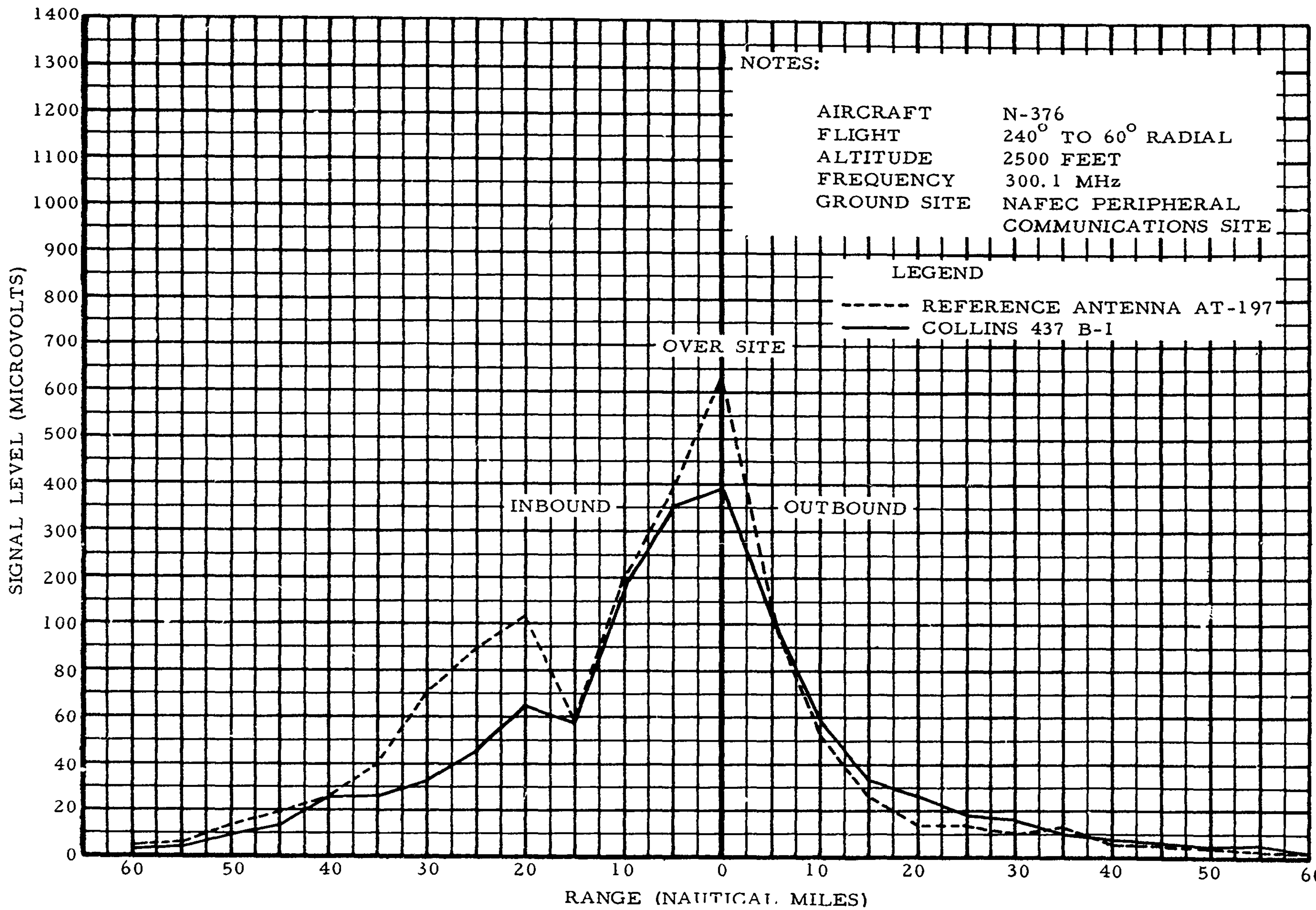


FIG. 40 RADIAL FLIGHT PATTERN OF UHF TYPE 437B-1 ANTENNA (240° TO 60° RADIAL)

Intercoupling Reduction/Polarization Test - Investigation of intercoupling reduction/polarization was accomplished at the DARTS Site, utilizing Type CA-5301 (3/4 of an inch diameter elements); and, CA-1563A (1 inch diameter elements) VHF Swastika Antennas.

Frequently at field sites, where there is a requirement for installing additional circular polarized swastika antennas, the existing physical space is a limiting factor in providing separation between antennas for needed isolation. The objective of this test was to experiment with different mounting configurations of swastika antennas of similar and dissimilar polarization (e. g., clockwise/clockwise or clockwise/counter-clockwise) to determine the degree of antenna intercoupling provided in each configuration. Test conditions consisted of mounting two swastika antennas in the same horizontal plane with 10 feet of separation between them, and then similarly, in the vertical plane. RF absorbent material was placed on the asphalt pad beneath the antennas to minimize ground reflections. A similar test was performed with two swastika antennas modified to provide dissimilar polarization. The results of these tests are presented in Table VII.

TABLE VII

INTERCOUPLING REDUCTION/POLARIZATION RESULTS

Two swastika antennas with similar polarization. Horizontal separation 10 feet and in the same plane.

TEST FREQUENCY (MHz)	DECOUPLING (dB)
119.0	24.8
126.0	24.8
131.0	26.0

Two swastika antennas with dissimilar polarization. Horizontal separation 10 feet and in the same plane.

TEST FREQUENCY (MHz)	DECOUPLING (dB)
119.0	31.5
126.0	33.6
131.0	35.5

"wo swastika antennas with similar polarization. Vertical separation 10 feet and in the same plane.

TEST FREQUENCY (MHz)	DECOUPLING (dB)
119.0	31.0
126.0	34.0
131.0	36.0

Two swastika antennas with dissimilar polarization. Vertical separation 10 feet and in the same plane.

TEST FREQUENCY (MHz)	DECOUPLING (dB)
119.0	33.5
126.0	38.0
131.0	42.0

Because of the encouraging results obtained from the tests with dissimilar polarized antennas, a special fixture was fabricated (Figure 41) to implement tests to determine further improvements in decoupling from more precise orientation of the individual antennas. Results of these tests indicated that the orientation of the antennas was critical for maximum decoupling. For example, it was determined by manually positioning the antennas to effect minimum coupling that de-decoupling of 38 dB could be obtained with only 6 feet of separation; whereas, with 10 feet of separation decoupling was 50 dB. The minimum coupling of the vertically stacked antennas was determined utilizing a receiver and signal generator. The receiver was connected to one antenna while the signal generator was connected to the other antenna. Only one of the two antennas was rotated to determine the physical position that produced minimum coupling. The amount of decoupling provided for a particular antenna separation and precise orientation was established as the ratio in dB between the receiver signal level coupled through the antennas, to the receiver signal level resulting from direct connection of the receiver and signal generator.

Although precise orientation of the dissimilar polarized antennas in the horizontal configuration was not performed, it is anticipated that similar decoupling improvement would also have been obtained for the horizontal configuration as a result of the refinement to the test.

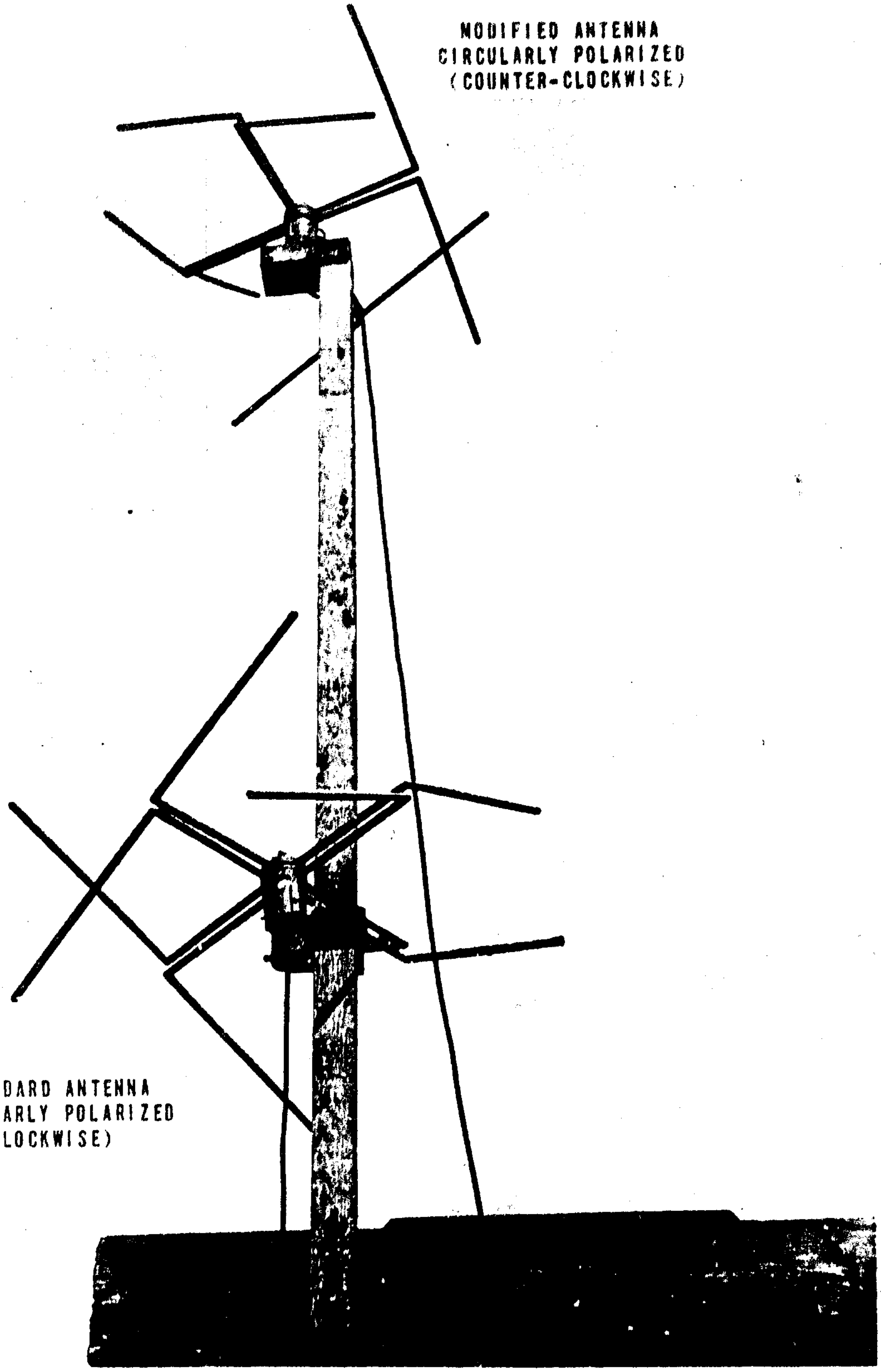


FIG. 41 DISSIMILAR POLARIZED ANTENNAS STACKED VERTICALLY ON WOOD MAST

Antenna Noise Measurements - Noise measurements were accomplished on the swastika and coaxial vertical polarized antennas to determine which antenna was most susceptible to low frequency (ignition-type) noise.

The test was performed at the Experimental Peripheral Communications Facility using the Coaxial Type CA-1511 and Swastika CA-1781 Antennas. For the initial test, the antennas were positioned near the motor-generator auxiliary power source, and the noise was measured with a Field Intensity Meter, Empire Devices, Type NA-105.

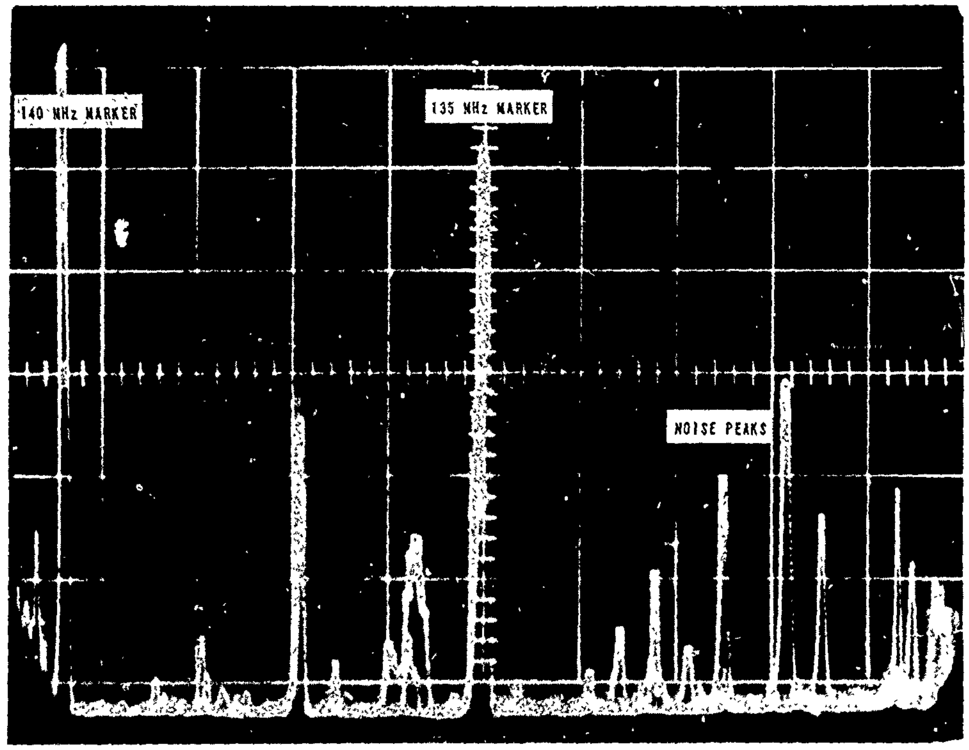
The noise measured from the swastika antennas was one decibel greater than the noise measured from the coaxial antenna.

A second test was accomplished with the antennas located on the antenna towers at the site utilizing an induction spark coil as a noise source. A Polarad Spectrum Analyzer TS A-S, Model DU-3A, was used to measure the noise peaks. The analyzer was adjusted to a center frequency of 135 MHz with a sweep bandwidth of 10 MHz and sensitivity of -70 dBm.

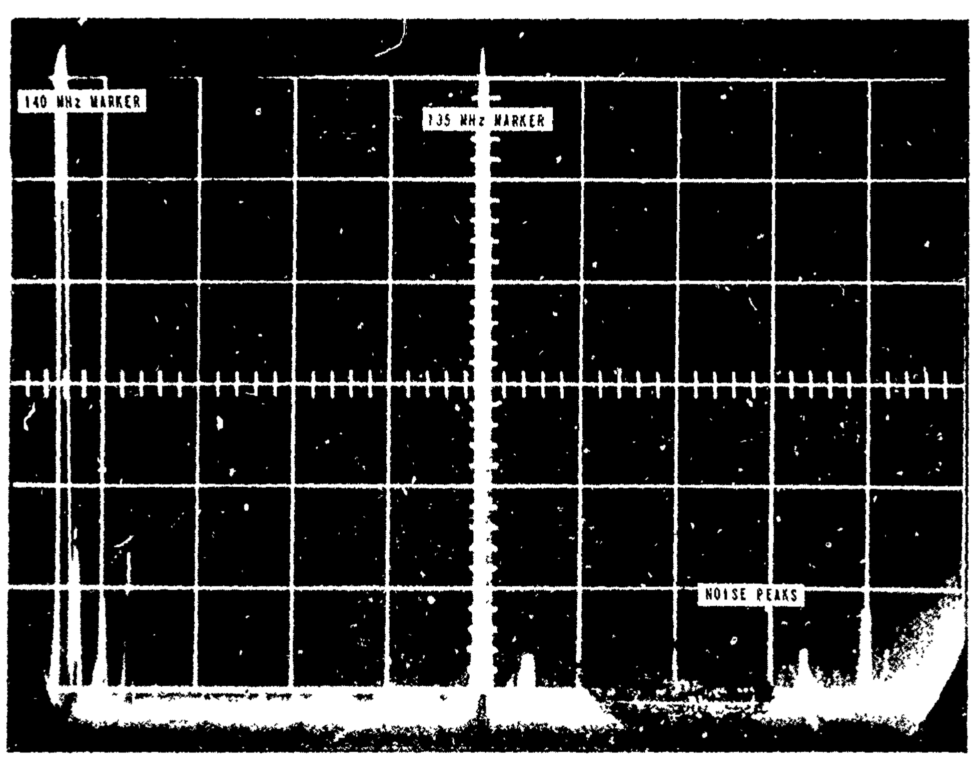
Results of the test shown in Figure 42 indicate that the maximum peak amplitude of noise measured from the swastika antenna exceeded the noise peaks from the coaxial antenna by 3 dB.

Inclement Weather Tests on Antennas at RCAG Sites - Tests were performed at RCAG sites in Montoursville and Phillipsburg, Pennsylvania, on various antenna designs to determine their capability for resistance to icing conditions during inclement weather. Scanwell Type FA-5676X and Collins Type 437B-1 UHF Antennas were installed at each site, reference Figures 43 and 34 respectively. At the Phillipsburg site, silicone rubber heaters were attached to existing VHF swastika and UHF disc-cone antennas to implement a phase of the tests using standard antennas.

The Collins Type 437B-1 Antenna consists of two-center-fed half wave dipoles collinearly arrayed and fed in phase. The elements are each approximately one-half-wave length at 300 MHz and are incapsulated in a fiberglas radome. The elements are suspended in foam dielectric to minimize the effects of shock and vibration. The antenna



a. VHF SWASTIKA ANTENNA TYPE CA-1781



b. VHF COAXIAL ANTENNA TYPE CA-1511

FIG. 42 ANTENNA NOISE SUSCEPTIBILITY MEASUREMENTS

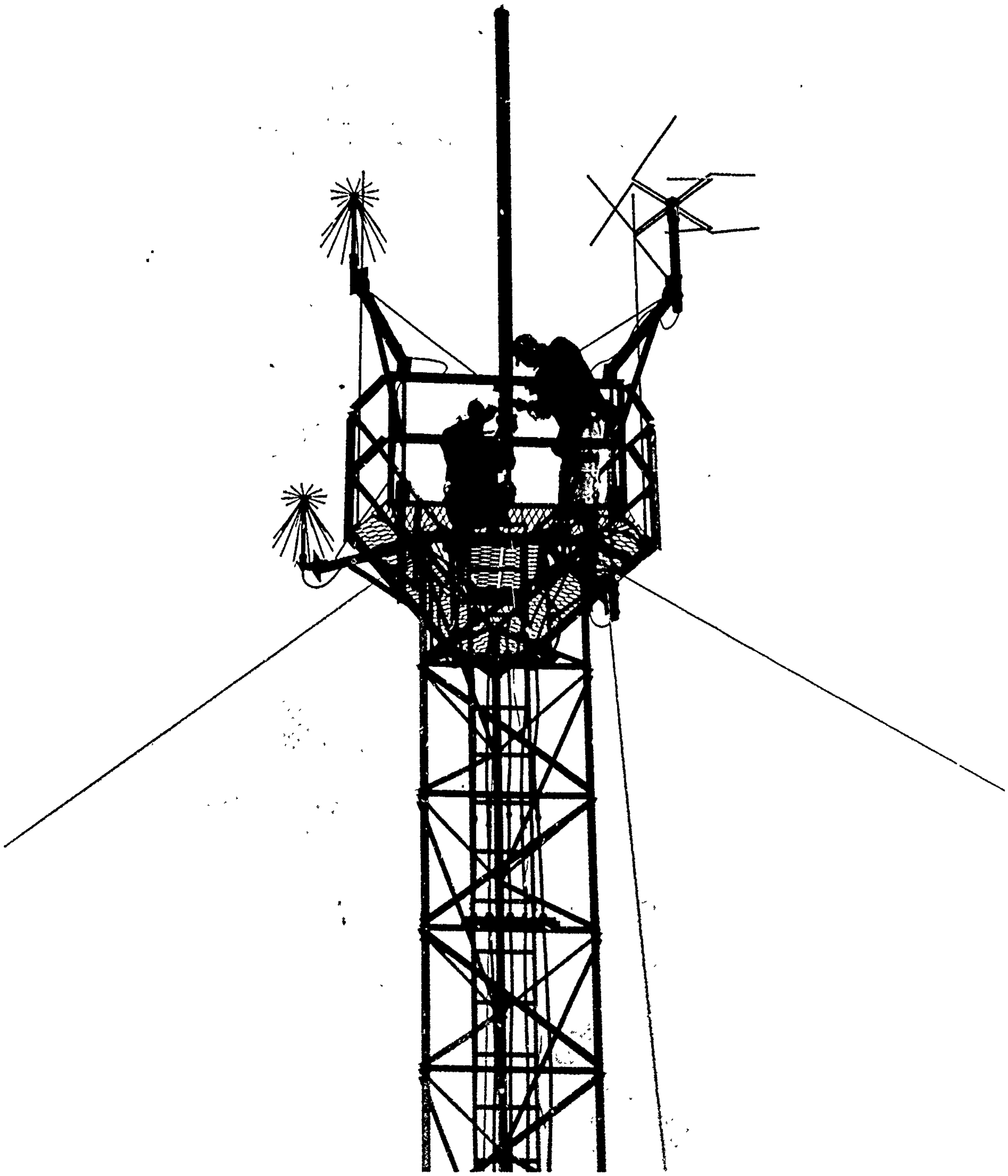


FIG. 43 INSTALLATION OF UHF TYPE FA-5676X ANTENNA

was considered applicable for these tests because of its geometric configuration and apparent resistance to the effects of icing conditions. The Scanwell Type FA-5676X Antenna is described on Page 21.

Antenna modifications made at the Phillipsburg RCAG site are shown in Figures 44 and 45. A detailed view of the silicone rubber heaters and temperature control is shown in Figure 46. The heater elements were fabricated by the Watlow Electric Manufacturing Company, Inglewood, California. The heaters for the swastika antennas were made up in 12-inch lengths and in diameters to accommodate either the 3/4-inch or 1-inch diameter antenna elements. The heater for the disc-cone antenna was 2-inches wide and cone shaped. The 1-inch diameter heater elements were designed to provide 180 watts of heat, the 3/4 inch diameter element 140 watts, and the cone shaped element 100 watts. The heater elements were attached to the antennas with Scotch Brand Glass Fibre Tape; however, for a permanent installation, they should be cemented to the antenna elements to provide more efficient heat transfer. Voltage Standing Wave Ratio (VSWR) tests were performed on both the VHF and UHF antennas with and without the heaters attached. Results of these tests indicated that the differences in VSWR were negligible (less than . 2 spread).

For the evaluation of the silicone rubber heaters, the temperature control unit was adjusted to actuate heaters when the temperature fell below 35°F and to turn off the heaters when the temperature rose above 40°F.

The inclement weather tests at the Montoursville and Phillipsburg RCAG's were performed during the period from January 14 through April 29, 1966. In general, the results of the tests were favorable although the weather conditions at the sites during the test period were not particularly severe, but considered moderate. It was determined that the design configuration of the Collins Type 437B-1 antenna (antenna elements enclosed in a radome) was effective for reducing communication outages due to icing in inclement weather. The Scanwell Type FA-5676X and the existing VHF and UHF antennas equipped with heaters were also effective. Figures 47 and 48 show snow and ice forming on the swastika and disc-cone antennas during a snow storm. Conversely, Figures 44 and 45 previously referenced show similar antennas equipped with electric heaters and provide evidence of the capability of these heaters for keeping the antennas free of snow and ice accumulations. Figure 49 shows melted ice accumulating at the base of the heated Scanwell UHF antenna.

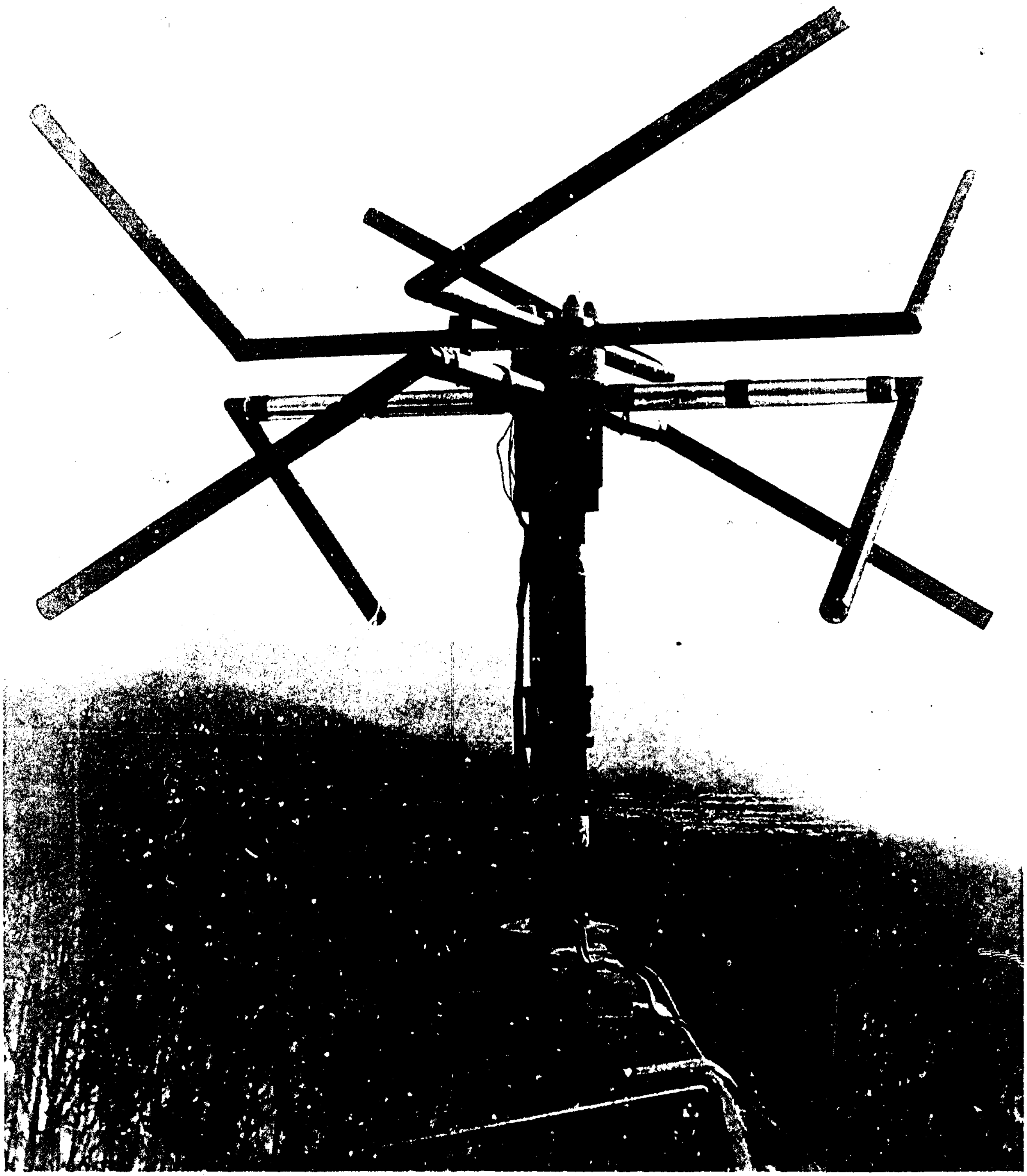


FIG. 44 VHF SWASTIKA ANTENNA WITH SILICONE RUBBER HEATERS ATTACHED

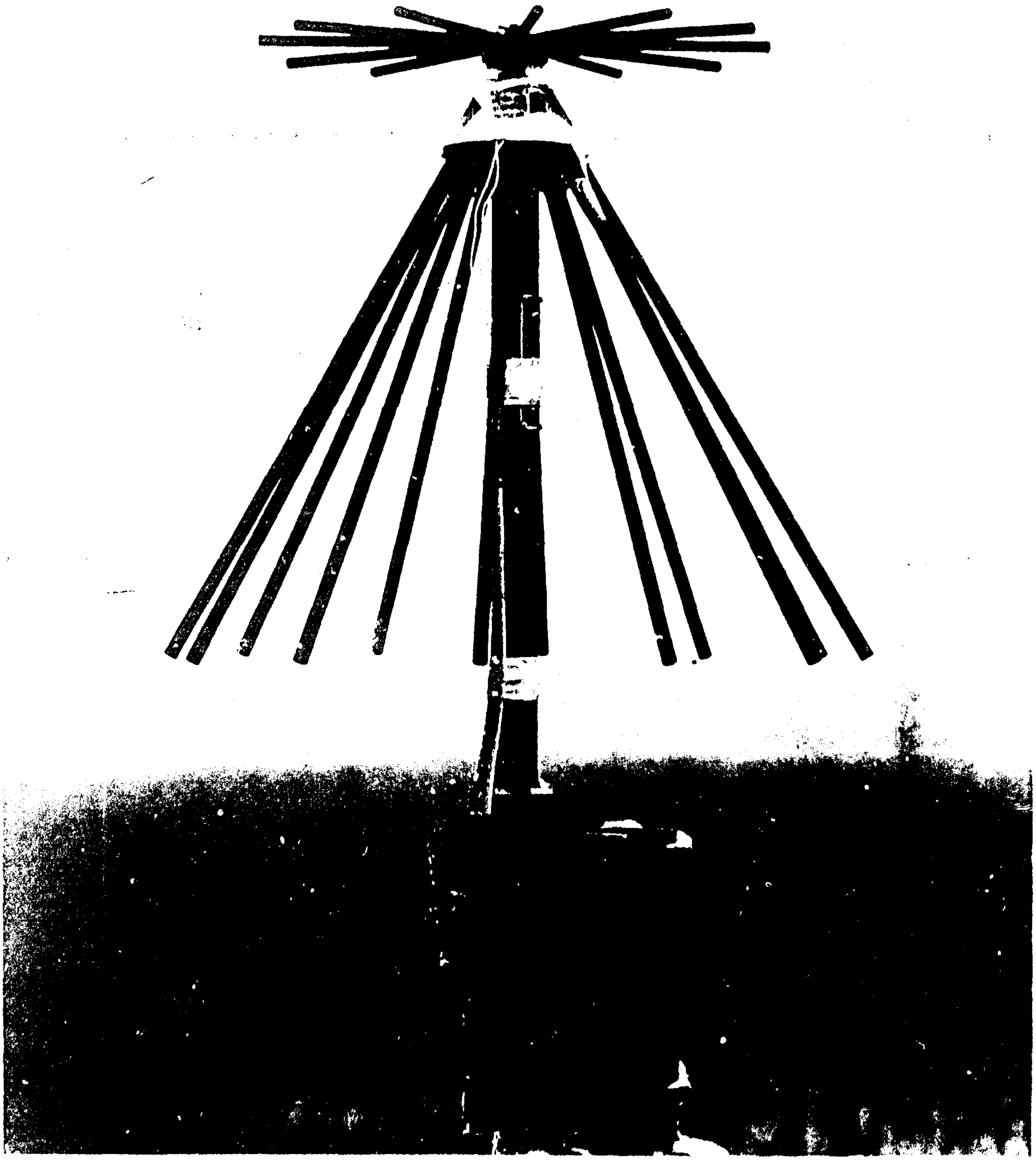


FIG. 45 UHF DISC-CONE ANTENNA WITH SILICONE RUBBER HEATERS ATTACHED

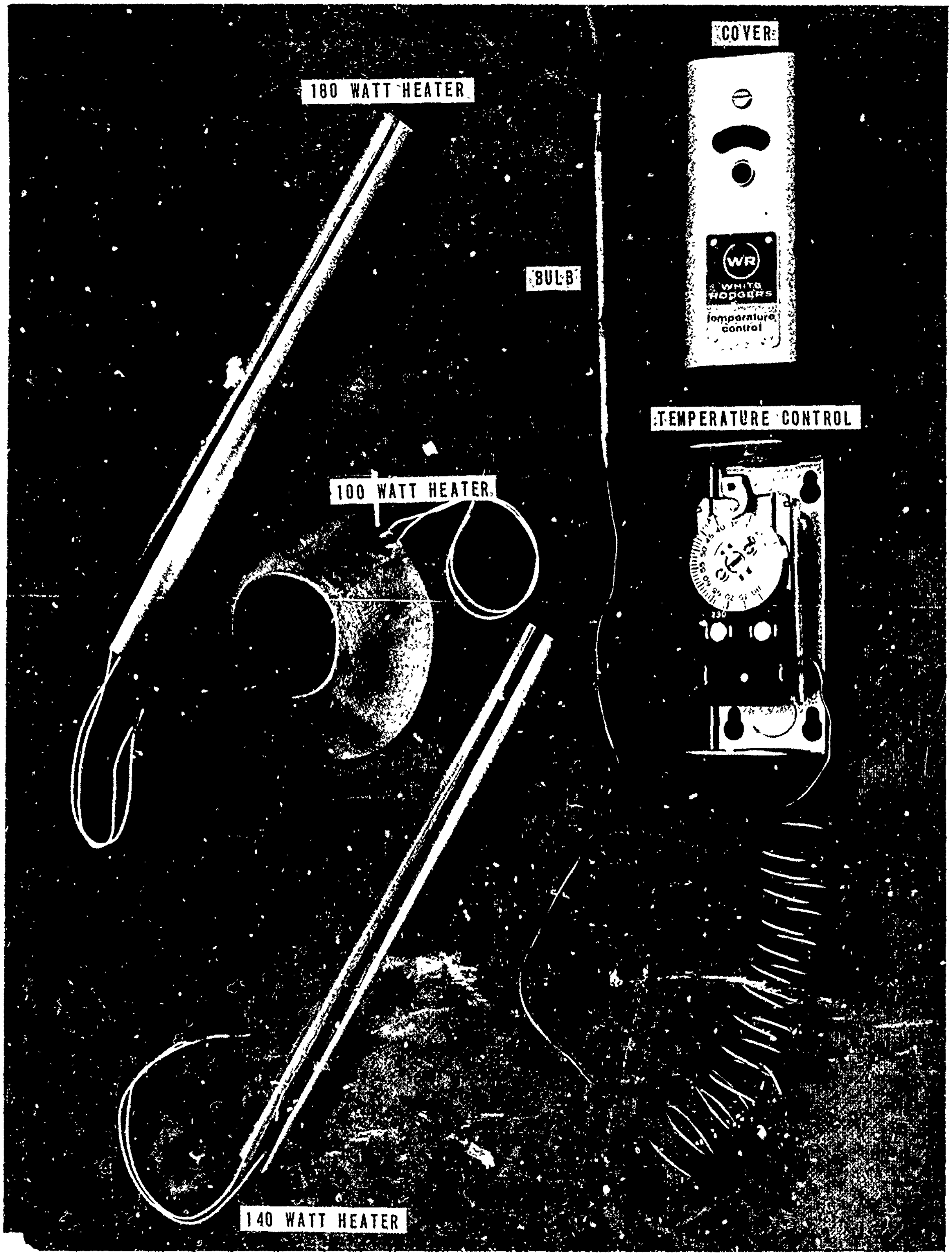


FIG. 46 DETAILED VIEW OF SILICONE RUBBER HEATERS AND TEMPERATURE CONTROL

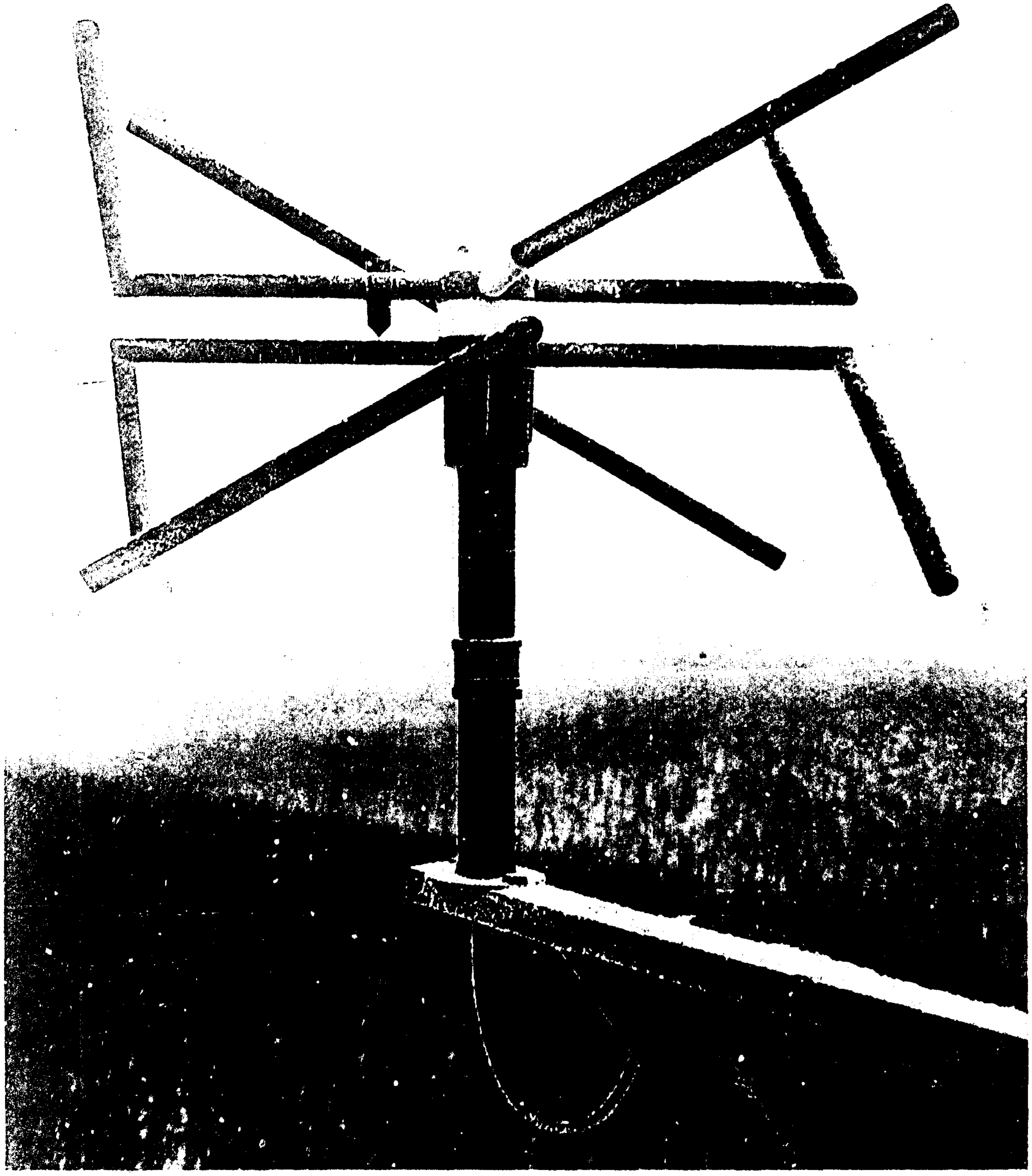


FIG. 47 ICE FORMING ON VHF SWASTIKA ANTENNA WITHOUT HEATERS

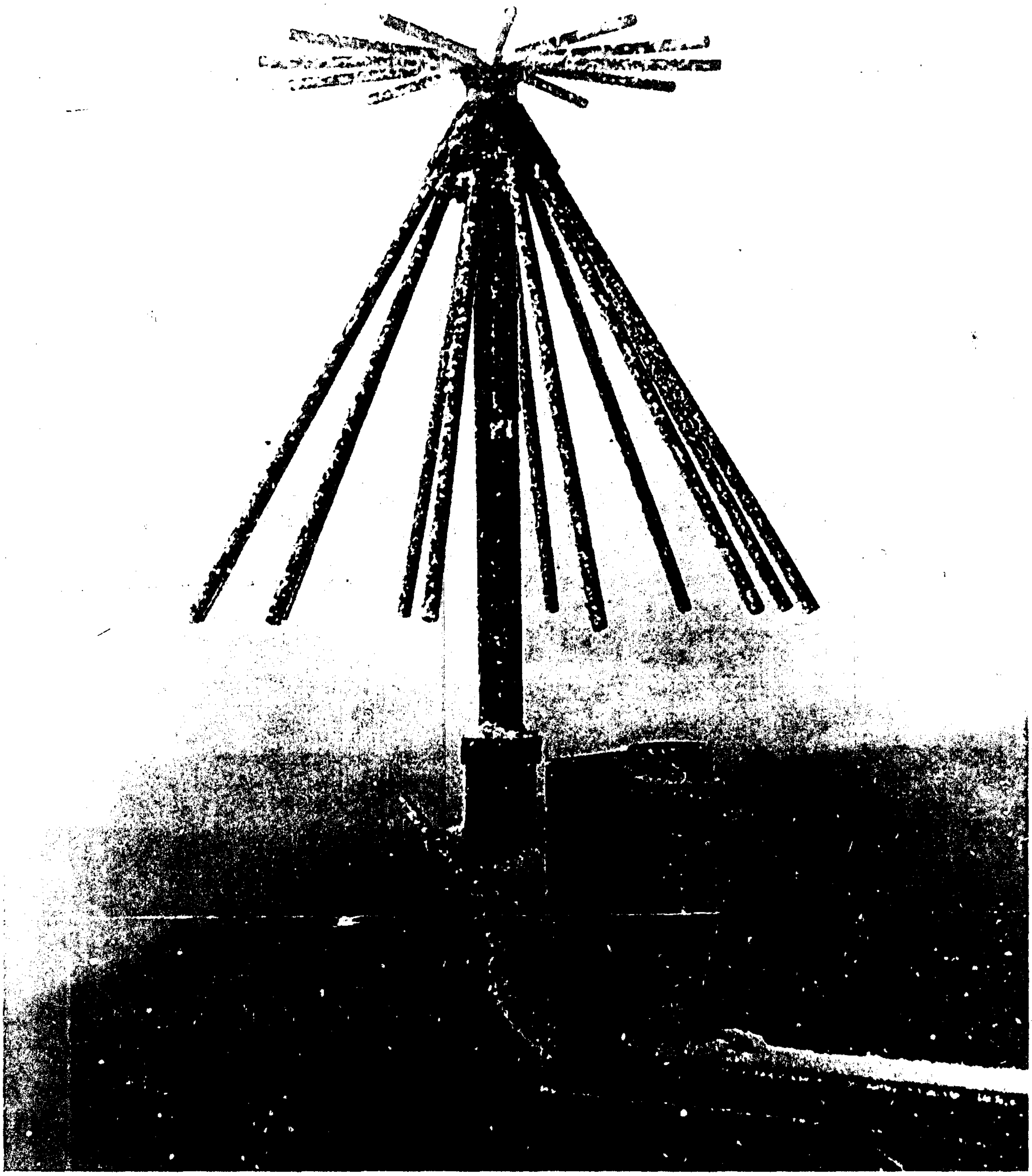


FIG. 48 ICE FORMING ON UHF DISC-CONE ANTENNA WITHOUT HEATERS

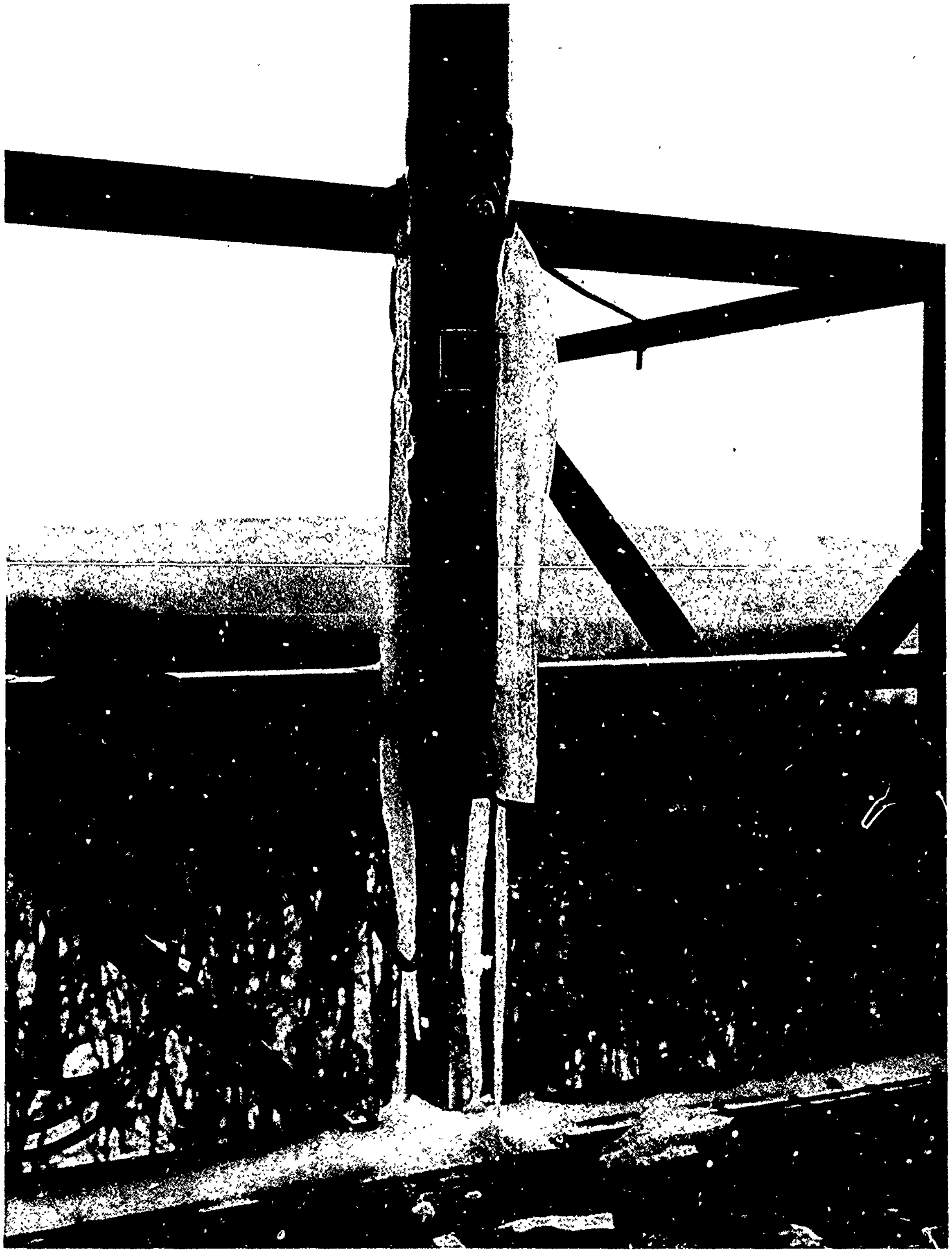


FIG. 49 ICE FORMATION AT BASE OF UHF TYPE FA-5676X ANTENNA

During the test period it was necessary for the Systems Maintenance Sectors personnel to remove ice from antennas not equipped with heaters, to prevent damage to the antennas and to correct radiation pattern coverage deficiencies.

It should be noted that two Scanwell Type FA-5676X Antennas were also provided to the Southwest Region, SW-430, for installation and environmental tests at their Sandia Crest, New Mexico, RCAG site. Appendix II contains a condensed environmental test report, provided by SW-430, which presents pertinent comments on the antenna installation and test results.

Evaluation of Foam Dielectric Cable: Spirofoam (foam dielectric) semi-flexible coaxial cable was installed at the NAFEC Experimental Peripheral Communications Facility to determine its performance characteristics, installation procedure and suitability for use with existing and planned FAA communications facilities.

Installation Procedure - To implement cable installation, ducts (Figure 50) were positioned, in the excavations provided for the cable runs, at each antenna tower and at the facility building as cable entrances. The ducts were 6 inches in diameter with a 90° bend. Four cable runs of seven-eighths inch diameter Spirofoam were made from inside the building to the top of each antenna tower. Cables located in the trenches were covered with earth fill. Waterproof junction boxes were installed on the railing of each tower platform to provide an enclosure for the transition from seven-eighths inch to one-half inch diameter Spirofoam cable. The 1/2-inch cable was used for connecting the antennas to the junction box and for interface to the equipment in the building.

Figure 51 shows a modified Junction Box (FSN #5940-351-228). Five 1 1/4-inch and five 7/8-inch diameter holes were drilled in the box. These holes were fitted with rubber grommets sizes three-fourths inch and one-half inch respectively. Spirolok connectors (Prodelin #75-880) Type N female were used to terminate the 7/8-inch Spirofoam cable and Spirolok (Prodelin #76-580) Type N male were used to terminate the 1/2-inch Spirofoam cable.

Figures 52 and 53 show selected views of the installation in the building. The spirofoam 7/8-inch diameter cable was terminated in Spirolok connectors (Prodelin #76-880) Type N Male. The 1/2-inch Spirofoam was used for the interconnection between the large cable and the equipment. Spirolok connectors (Prodelin #75-580) Type N female

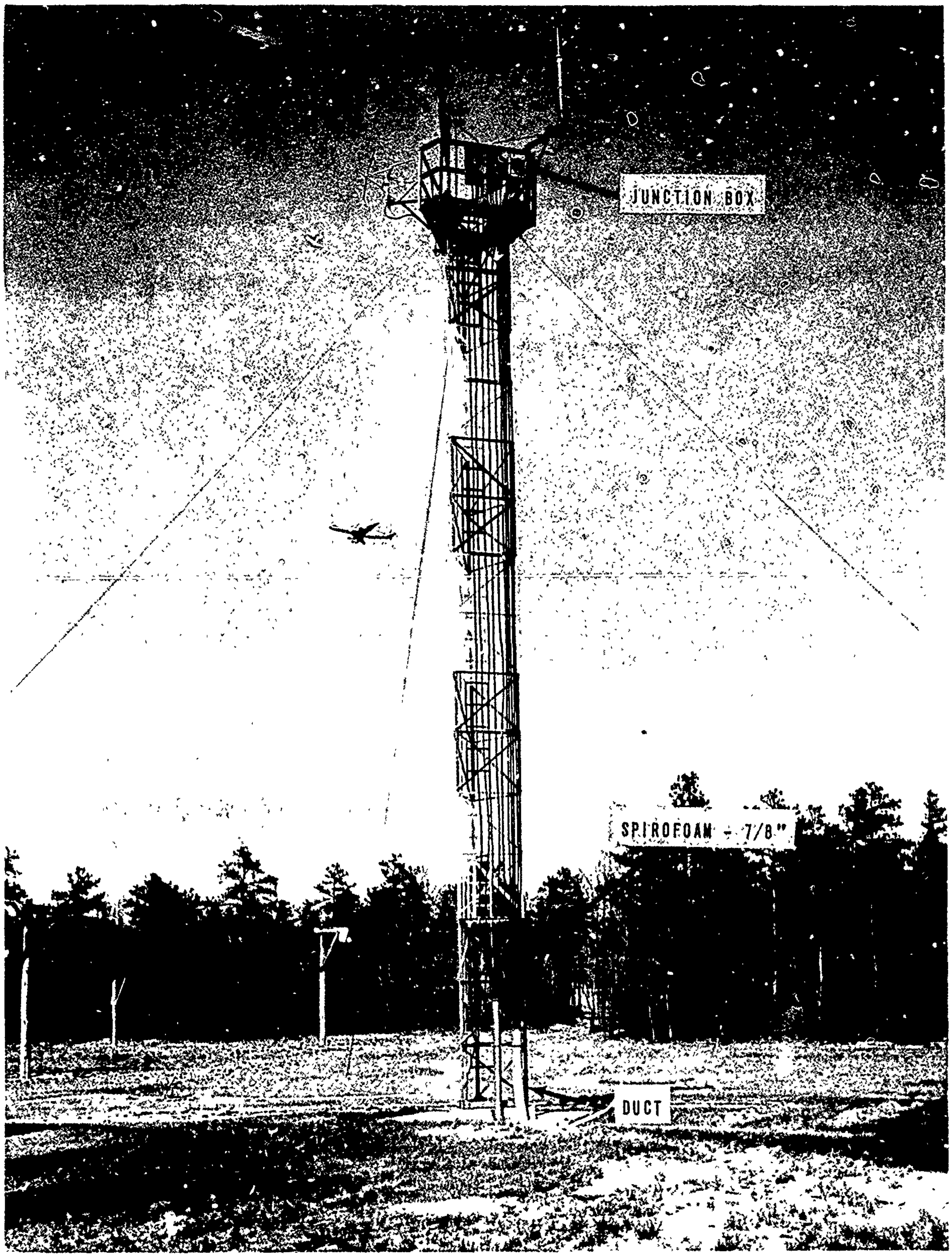


FIG. 50 SPIROFOAM INSTALLATION AT THE NAFEC EXPERIMENTAL PERIPHERAL COMMUNICATIONS FACILITY

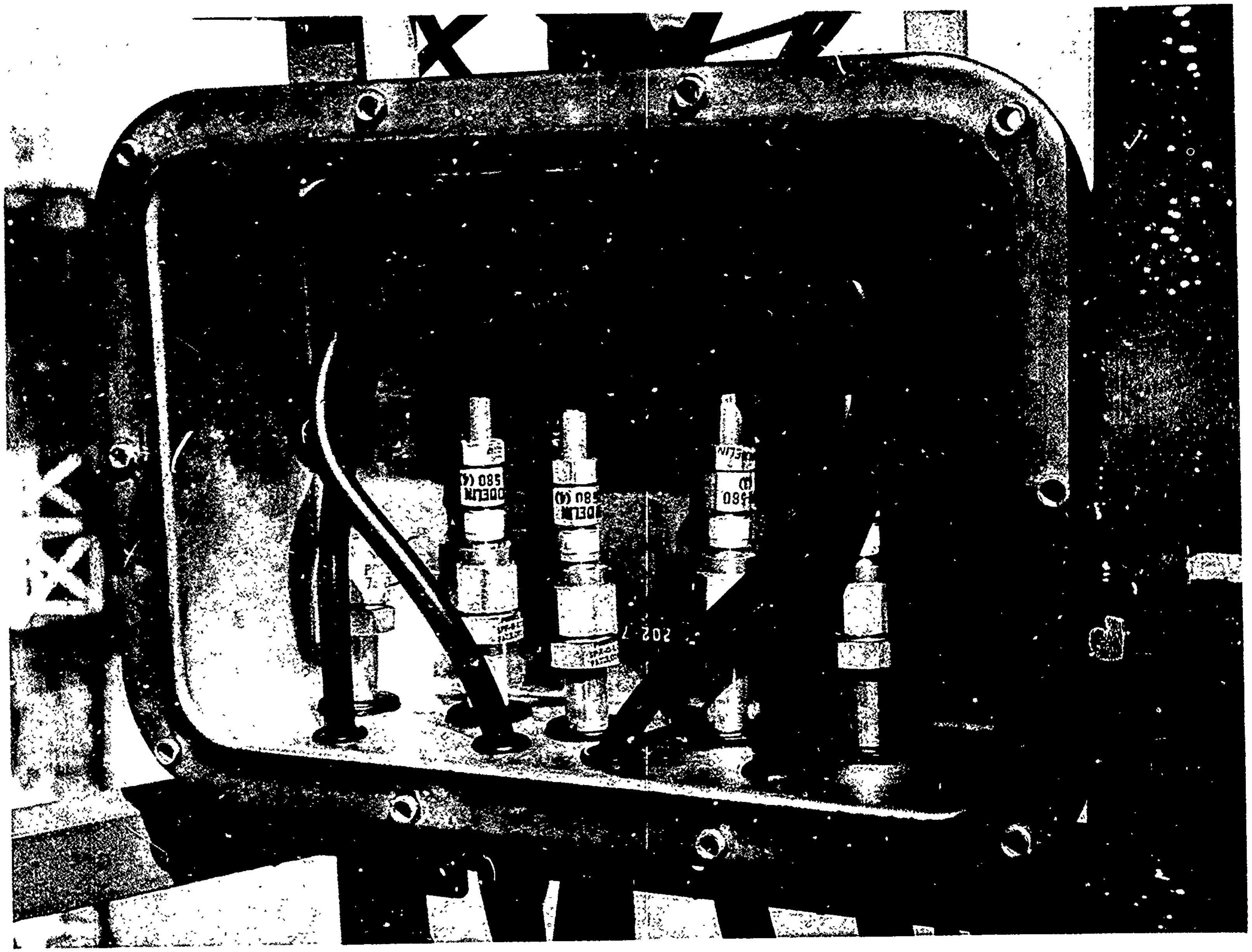


FIG. 51 MODIFIED JUNCTION BOX

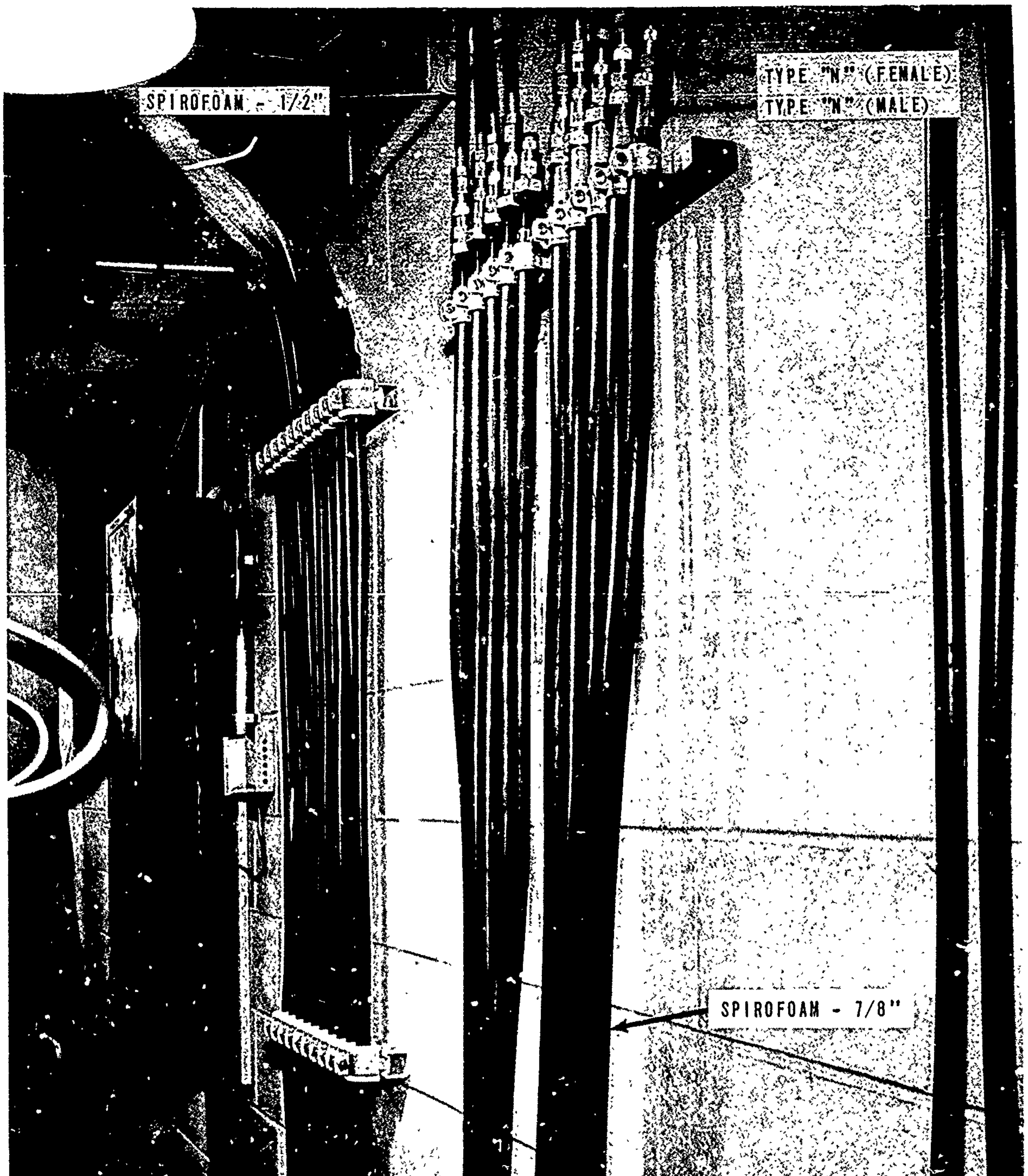


FIG. 52 VIEW OF SPIROFOAM INSTALLATION IN THE FACILITY BUILDING

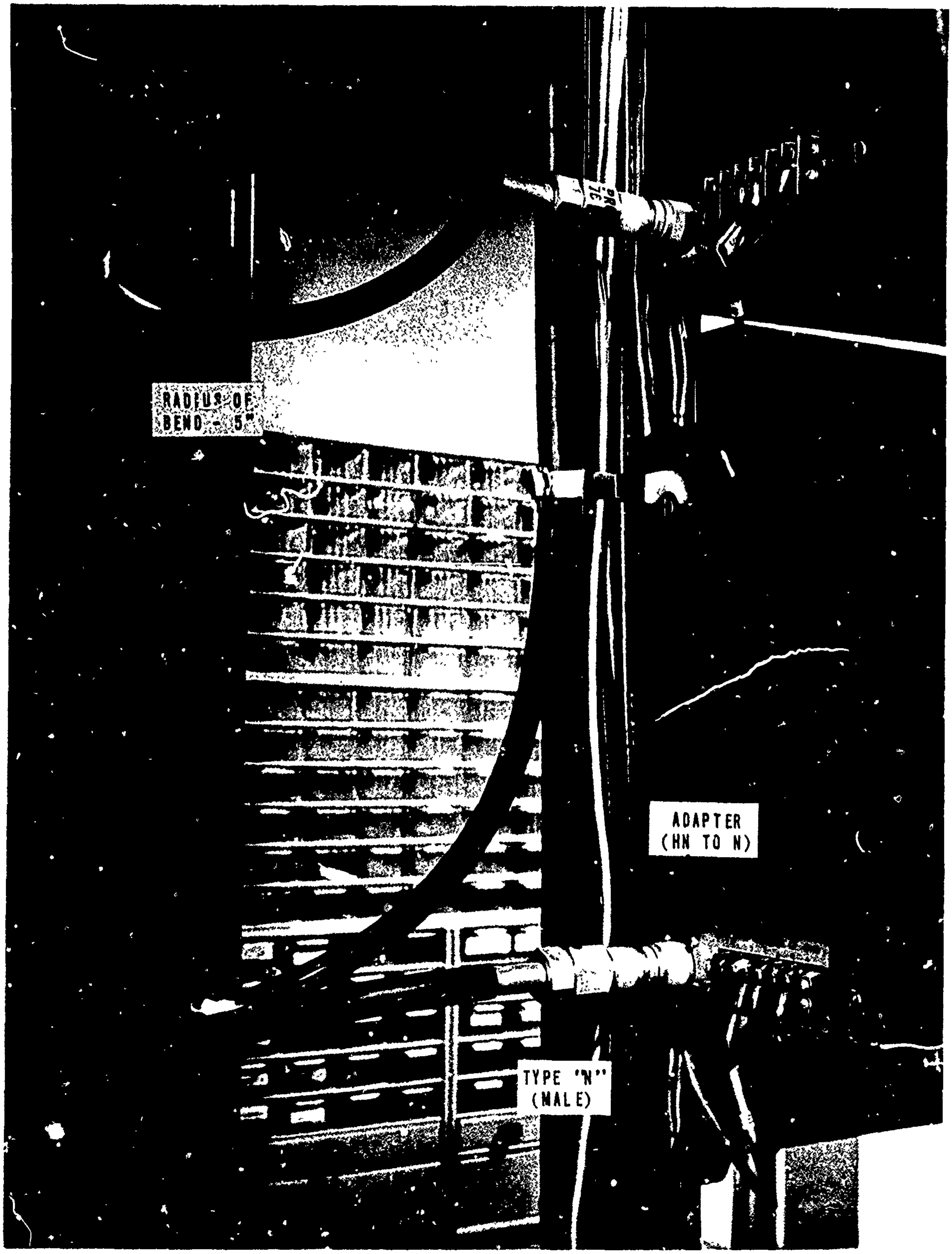


FIG. 53 VIEW OF SPIROFOAM CABLE CONNECTIONS TO THE UHF EQUIPMENT

were used to join the two different size Spirofoam cables. Connection to the UHF transmitters and receivers required use of a Type HN to N adapter. Figure 54 shows the detailed assembly of the Spirolok connectors. No special tools are required to install the connectors on the Spirofoam cable and the connectors can be re-employed many times without replacing parts. The two tapered sleeves assure a positive connection to the cable. The holding sleeve has grooves machined at an angle and is designed to skive into the cable. Solder connection to the inner conductor is not necessary, because the design of the Spirofoam cable eliminates conductor pull-out.

For installation purposes, it should be noted that the minimum bend radius of the 1/2-inch and the 7/8-inch diameter Spirofoam cable is 5 and 10 inches, respectively.

Cable Tests - Tests were performed: (1) at the Experimental Peripheral Communications Facility to determine the transmission loss of the 7/8-inch diameter Spirofoam cable runs in comparison with the existing RG 17/U cable; and (2) at the NAFEC Environmental Chamber, to determine the susceptibility of the Spirolok connectors and Spirofoam cable to extreme temperature changes.

The Spirofoam cable loss was measured by connecting two cable runs together at the top of the antenna tower and measuring the level of an RF reference signal, first through the cables and then directly from the signal source to the measuring device. Spirofoam and RG 17/U cables on all four towers were measured in this manner. Table VIII lists the single averaged values of transmission line loss for 120-foot lengths of cable at selected VHF and UHF frequencies.

TABLE VIII

TRANSMISSION LINE LOSS FOR 120-FOOT LENGTHS OF CABLE

Test Frequency (MHz)	Cable Type	Line Loss in dB
118.2	Spirofoam	0.68
118.2	RG 17/U	1.38
134.9	Spirofoam	0.73
134.9	RG 17/U	1.53

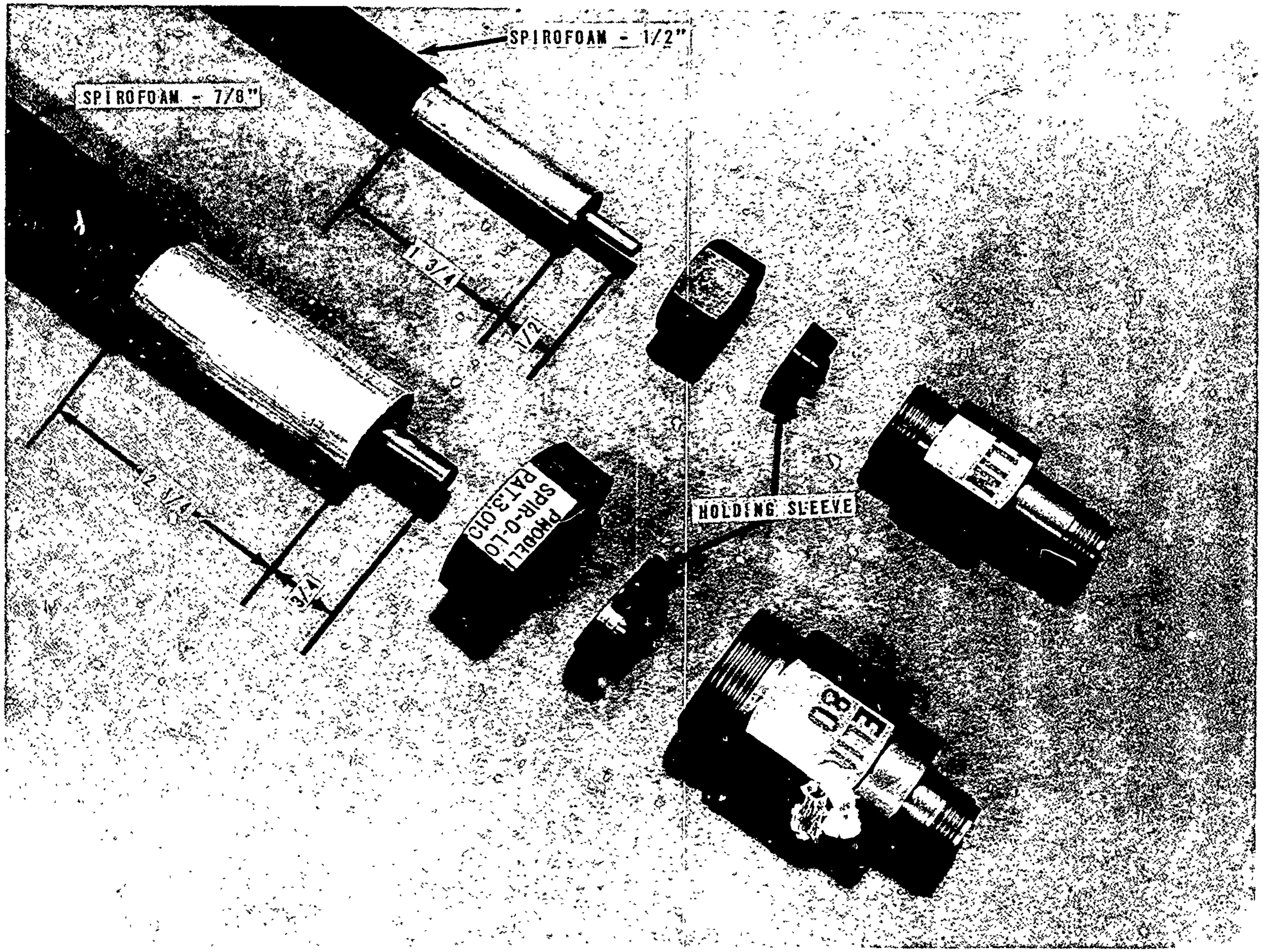


FIG. 54 DETAILED ASSEMBLY OF SPIROLOK CONNECTORS

TABLE VIII (continued)

Test Frequency (MHz)	Cable Type	Line Loss in dB
150.2	Spirofoam	0.78
150.2	RG 17/U	1.62
225.0	Spirofoam	0.95
225.0	RG 17/U	2.07
300.0	Spirofoam	1.15
300.0	RG 17/U	2.48
399.9	Spirofoam	1.27
399.9	RG 17/U	2.92

Results of these tests indicate a 0.70 to 1.65 dB improvement within the frequency range of 118.2 to 399.9 MHz by using 7/8-inch diameter Spirofoam cable in lieu of RG 17/U cable. Current field practice for transmission line installations at standard RCAG facilities is to use RG 17/U cable for the long runs and RG 8/U cable for patching these runs to the antennas on the towers and equipment in the facility building. A typical maximum length cable run for the worst case conditions (399.9 MHz) is 120 feet of RG 17/U and 46 feet of RG 8/U. From standard tables of cable losses it can be seen that the overall transmission line loss is 5.18 dB (2.88 dB, RG 17/U and 2.3 dB, RG 8/U). For an equivalent run of Spirofoam 7/8-inch and 1/2-inch, as substitutes of the RG 17/U and RG 8/U respectively, the line loss would be 2.15 dB (1.32 dB, Spirofoam 7/8-inch and 0.83 dB, Spirofoam 1/2-inch) or an improvement of 3.03 dB.

For information, a plot of the manufacturer's data for Spirofoam cable attenuation versus frequency is presented in Figure 55; related temperature correction factors are provided in Figure 56.

Environmental Test - Environmental test of the Spirofoam cable and Spirolok connectors was accomplished by installing lengths of 1/2-inch and 7/8-inch cable jointed by connectors in the environmental chamber as shown in Figure 57. Thermocouples were attached to the connectors, inserted inside a length of cable and positioned in the air flow surrounding the connectors and cable under test, to monitor the temperature changes.

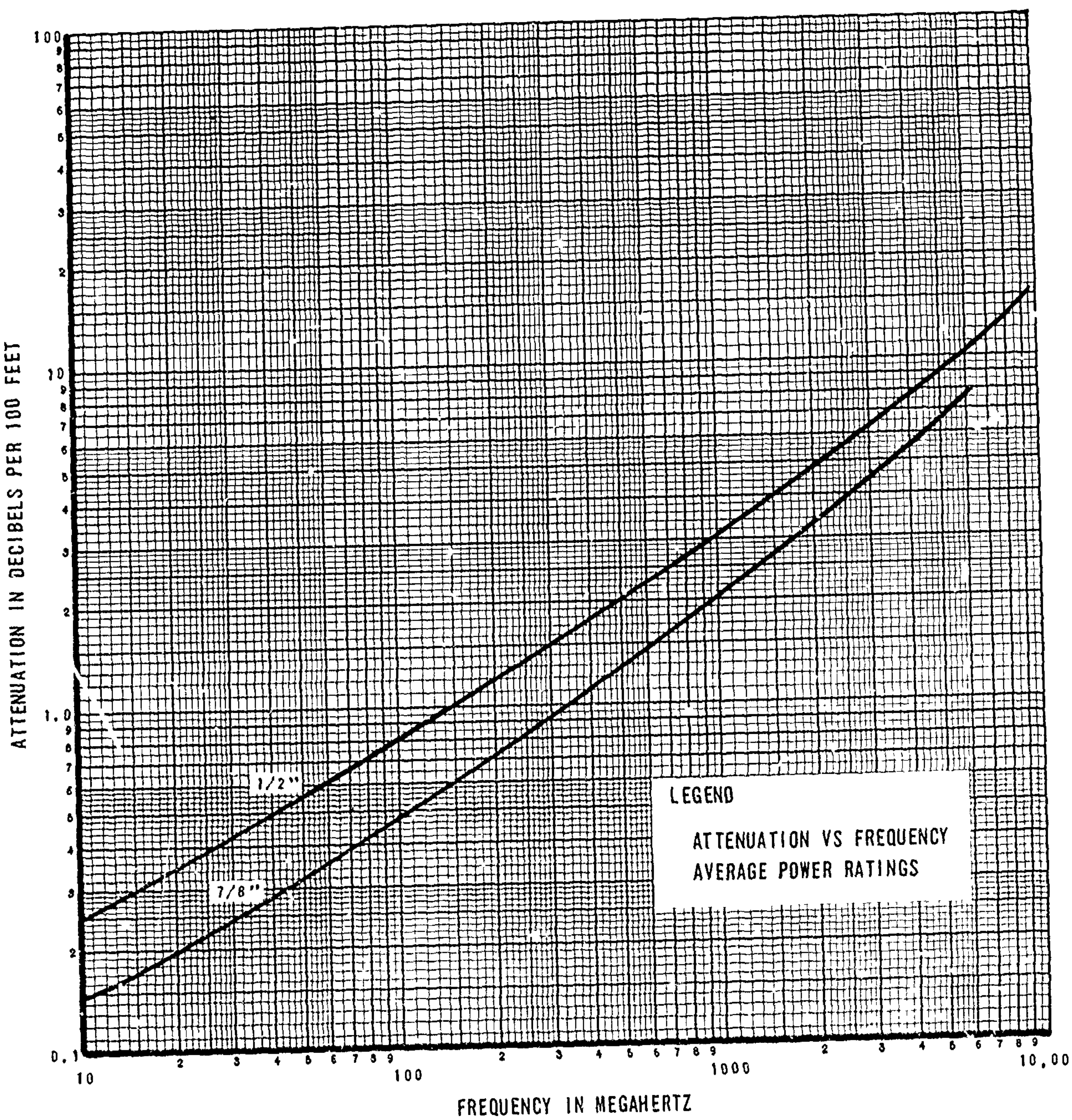


FIG. 55 SPIROFOAM CABLE ATTENUATION CHARACTERISTICS

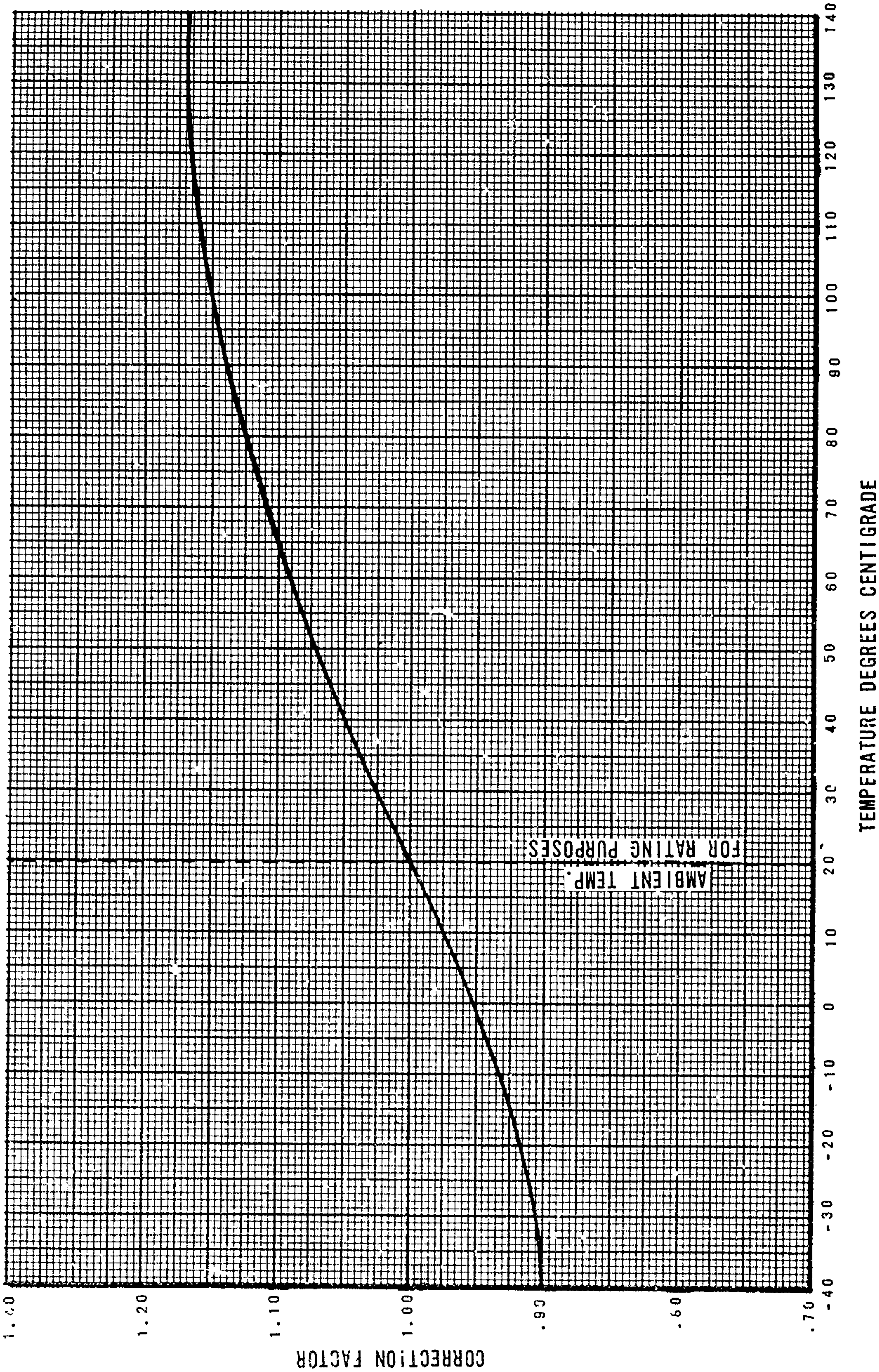


FIG. 56 SPIROFOAM CABLE TEMPERATURE CORRECTION FACTOR

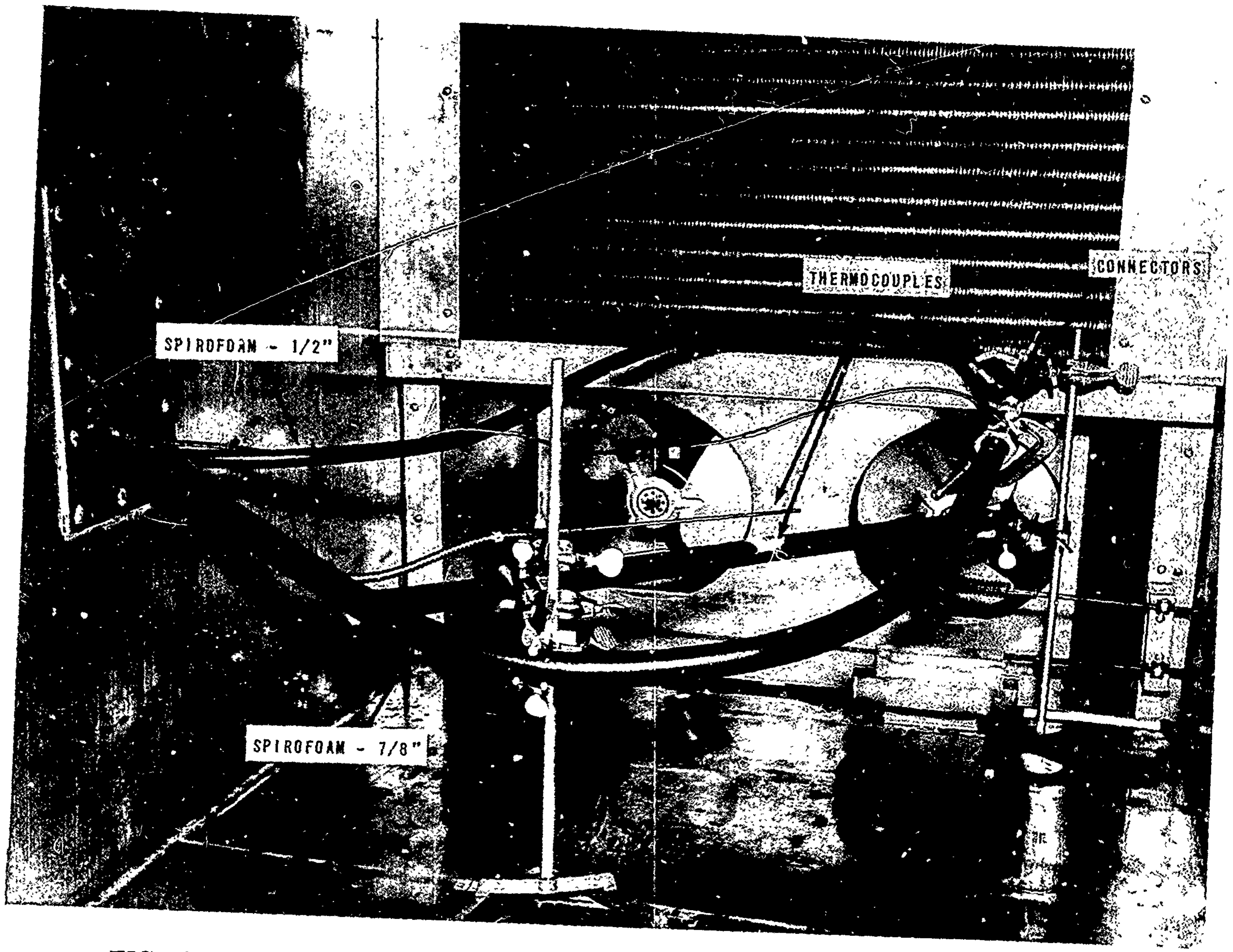


FIG. 57 SPIROFOAM CABLE AND SPIROLOK CONNECTOR CONFIGURATION FOR ENVIRONMENTAL TESTS

The instrumentation used for the tests (Figure 58) consisted of an Alford Manufacturing Compnay, Model 1026B-4 Slotted Line, used for measuring VSWR; and, Hewlett Packard, Model 415 Standing Wave Indicator, Model 408 Signal Generator, and Model 5343 Frequency Counter. The Spirofoam cable was terminated with a Hewlett Packard, Model 908A 50-ohm Termination.

The cables and connectors under test were subject to temperature extremes between $+80^{\circ}$ and -60° Centigrade with incremental changes of 20° from the highest to the lowest temperature. The temperature of the cables was stabilized for each temperature indicated. The VSWR of the cable/connector circuit was monitored throughout the test to determine susceptibility to the environmental conditions.

Results of the tests indicated that the Spirofoam cables and Spirolok connectors were not affected by the extreme changes in temperature. A VSWR of 1.04:1 was maintained for all test temperatures.

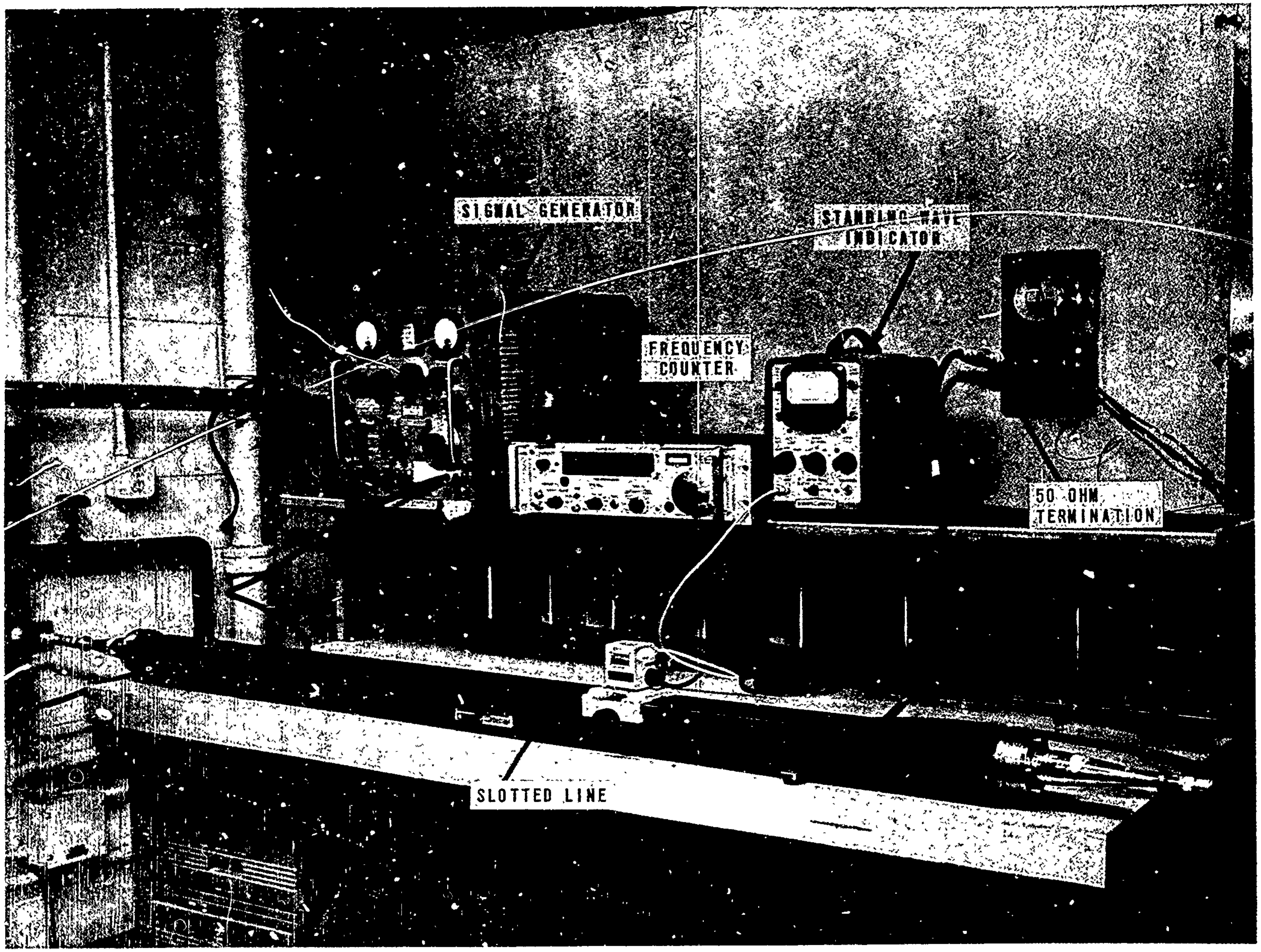


FIG. 58 INSTRUMENTATION CONFIGURATION FOR THE ENVIRONMENTAL TESTS

SUMMARY OF RESULTS

Results of the test and evaluation of VHF and UHF antennas have provided standard reference antenna radiation patterns and antenna gains for existing FAA and selected prototype antennas. As indicated by the free space patterns, the Scanwell Type FA-5676X Antenna exceeded the performance of the other UHF antennas tested with respect to antenna gain. The operational flight test accomplished on the antennas demonstrated variations in the antenna patterns due primarily to siting environment and to a lesser extent to antenna polarization and installation configuration. The gain improvement anticipated from using the Scanwell FA-5676X Antenna in lieu of an AT-197 at the Experimental Peripheral Communications Test Site was not evident in the results of the radial flight tests.

For VHF freqeuency applications, it was determined that the coaxial vertical polarized antenna was 3 dB less susceptible to ignition noise than the circular polarized swastika antenna. It was also determined that in installations requiring additional circular polarized antennas and where sufficient lateral spacing to effect needed isolation between antennas is unobtainable due to limited physical space, two dissimilar polarized antennas mounted vertically with 10 feet separation will provide up to 50 dB decoupling between the antennas.

The inclement weather test on antennas performed at commissioned RCAG facilities demonstrated the effectiveness of heated antennas in preventing loss of communications due to icing conditions. Low cost silicone rubber heaters were used advantageously on the VHF circularly polarized and UHF Type AT-197 Antennas.

Evaluation of the foam dielectric cable at the Experimental Peripheral Communications Facility indicated a 3 dB reduction in transmission loss was realized when this type cable was used in lieu of RG 17/U and RG 8/U in a cable run of 120 feet and 46 feet, respectively. Benefits represented by reduction in transmission loss are increased radiated power and increased signal level to the receiver. Improvement in coverage could be expected if Spirofoam cables were utilized at problem sites where communications are marginal.

CONCLUSIONS

Based upon the results of the test effort to obtain standard reference antenna patterns for existing FAA and selected prototype VHF and UHF antennas; and, investigation of antenna heating devices and foam dielectric cable, as potential in-service improvements, it is concluded that:

1. The standard reference antenna radiation patterns established as a result of this project effort are suitable for use as a baseline for future antenna evaluation and procurement specifications.

2. The variations in antenna radiation patterns for RCAG site applications are primarily influenced by siting environment, with lesser effects due to antenna polarization and antenna installation configuration.

3. Where available physical space precludes lateral spacing of circular polarized (swastika) antennas to effect needed isolation between antennas, vertically stacking two dissimilar polarized antennas (e.g., clockwise/counter-clockwise) with 10 feet separation will provide up to 50 dB decoupling between the antennas.

4. Antenna designs incorporating heaters are feasible for FAA application in geographical areas where large accumulation of snow and ice damage antennas and cause temporary outages in communications coverage.

5. Silicone rubber heaters are practical inexpensive devices for deicing existing problem FAA antennas such as the swastika and disc-cone design.

6. Utilization of a foam dielectric cable, with characteristics equivalent to the Spirofoam cable tested, in lieu of RG-17/U and RG-8/U for transmission lines will reduce now required cable maintenance and provide a reduction in transmission loss.

RECOMMENDATIONS

Based on the overall test effort with radiation systems, it is recommended that:

1. Antennas incorporating heaters be provided for geographical areas where large accumulations of snow and ice damage antennas and cause temporary outages in communications coverage.

2. Silicone rubber heaters be provided as a low cost device for modifying existing FAA swastika and disc-cone design antennas to correct operation deficiencies due to icing of antennas in inclement weather.

3. Spirofoam or equivalent type cable be utilized for transmission lines at FAA communication facilities in lieu of RG 17/U and RG 8/U.

4. Dissimilar polarized antennas be provided to decrease coupling between circularly polarized antennas when physical isolation is a constraint.

APPENDIX I

TEST PROCEDURE FOR

ANTENNA REFERENCE PATTERNS

This appendix presents the basic test procedures utilized in accomplishing the reference antenna pattern measurements. Test equipment utilized is also included.

1. The maximum gain of each antenna was compared to a calibrated standard gain antenna.

2. Antenna under test was employed in the receiving mode. This antenna was adjusted with respect to the source antenna in azimuth and elevation until the received signal was of maximum signal intensity as observed on the receiver/analyzer and polar recorder.

3. Attenuator pads in the receiving line were adjusted to provide a convenient reading for proper recording on the polar coordinate chart.

4. The antenna under test was then replaced with the standard gain antenna located at the electrical center, and a reference mark was made on the chart paper.

5. During the comparison, the transmitter power and receiver gain was maintained at a constant setting to satisfy the equation -

$$G = G_s + A - A_s$$

Where G = Gain of antenna under test
G_s = Gain of standard antenna
$A - A_s$ = Difference in attenuator settings.

6. Antenna patterns were recorded in the far zone region satisfying equation -

$$R \geq \frac{2D^2}{\lambda}$$

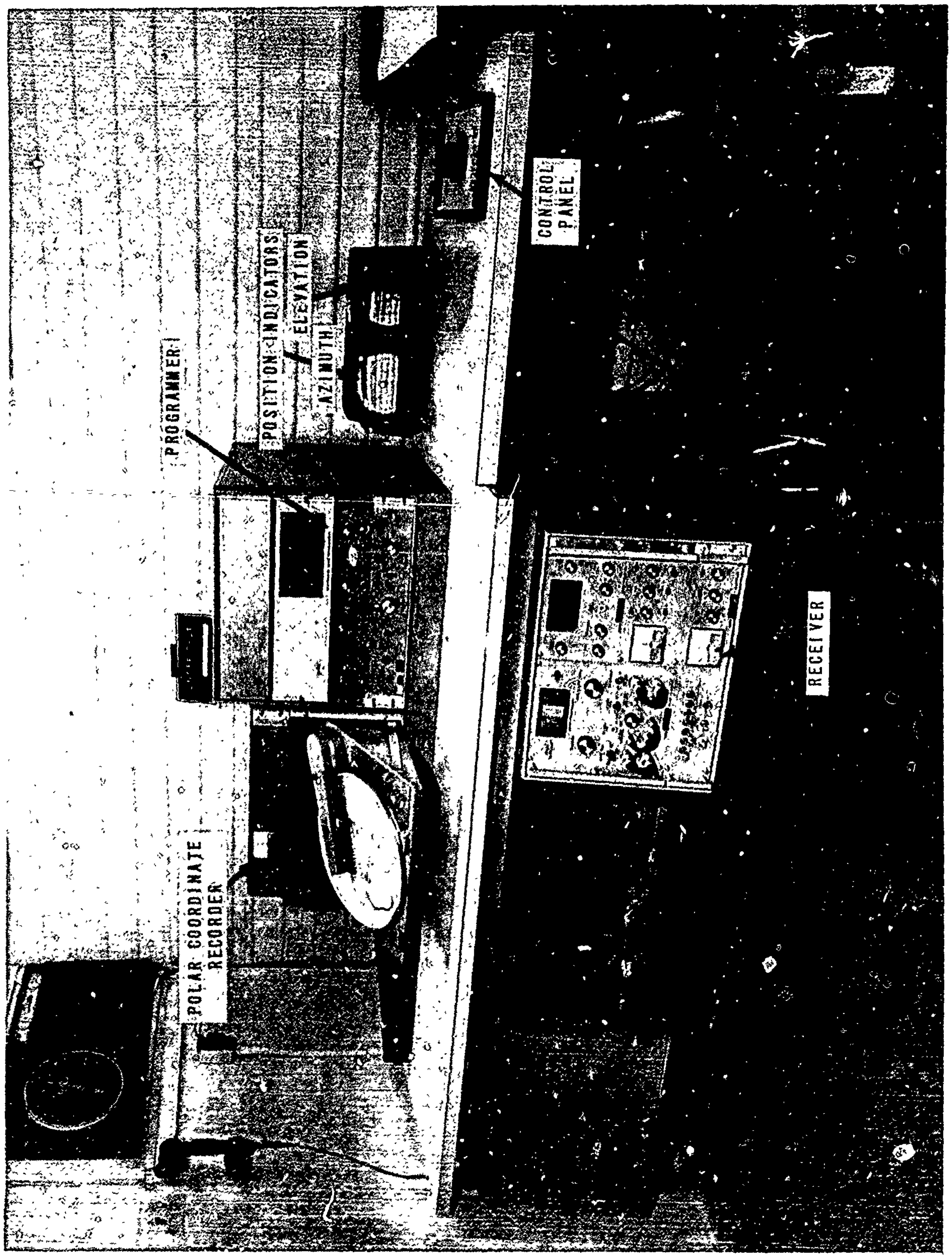
Where R = Range (Distance between antennas)
D = Largest aperture of either antenna receiving or transmitting
λ = Free space wave length of test frequency

7. The horizontal patterns were measured with the antenna under test mounted vertically and rotated in azimuth around its vertical axis.

8. The vertical patterns were measured with the antenna under test mounted horizontally and rotated in azimuth around its electrical center. This initial pattern was the 0° vertical pattern and served as the reference for the other vertical patterns. From this point the antenna was axially rotated 30° for each vertical pattern cut. Patterns were made at 0°, 30°, 60°, 90°, 120°, 150°.

Test Equipment

The equipments used in obtaining the antenna reference patterns (Figure 1-1) are as follows: Position Indicators, Antlab, Inc., Model 1631 (Azimuth) and Model 1630 (Elevation); Receiver, Scientific-Atlanta, Inc., Model 1640 APZ; Polar Coordinate Recorder, Scientific-Atlanta, Inc., Model 1550; Programmer, Scientific-Atlanta, Inc., Model 1558; Control Panel, Antlab, Inc., Model 3309-3.



1-1 ANTENNA RANGE INSTRUMENTATION

APPENDIX II

ENVIRONMENTAL TEST

(CONDENSED REPORT)

This Appendix presents the environmental test on the Scanwell, Type FA-5676X antenna accomplished by the Southwest Region, SW-430.

1. Site History
   a. Test site location: Sandia Crest, New Mexico
   b. Elevation of site: 10,678 feet msl
   c. Number and types of antennas located on same tower that will be used for mounting the FA-5676X antenna: Two disc-cone, one AS-505 (284.6 receiver), two each two-element yagi (165 MHz)
   d. Height of antenna above ground: 30 feet to base of antenna
   e. Type of terrain surrounding site: Rocky Mountain Ridges
   f. Number of UHF and VHF channels at site: Three UHF six VHF
   g. Type of climate normally experienced during winter: Heavy snow thick ice with winds up to 100 MPH
   h. Frequency of previous channel outages caused by antenna icing: Four or five per winter
   i. Was the disc-cone antenna ever previously damaged or destroyed at this site: Yes
   j. RF frequency at which the Type FA-5676X antenna will be operated: 284.6 MHz XMIT

II. Installation Comments
   a. Did antenna arrive in package without damage: Yes
   b. Can the antenna be installed or removed by one man: No
   c. Number of men necessary to accomplish safe installation: Minimum two, preferably three
   d. Was there any damage to the antenna during installation: No
   e. VSWR measurements of FA-5676X antenna at assigned frequency at time of installation: 1.05/1 or better
   f. Power input to FA-5676X antenna at time of installation: 70 watts
   g. Additional installation comments: Antenna was bolted to heavy four-inch angle-iron bracket which was bolted to the wooden pole supporting one corner of the Delta type antenna tower

III. Mechanical Performance

a. During heavy snow or icing conditions, how much accumulation and what was the VSWR noted on the -

(1) Disc-cone antenna: 1" on radials, 3" on barrel, VSWR 1.2/1

(2) Prototype FA-5676X antenna, heat on: None, VSWR 1.05/1

(3) Prototype FA-5676X antenna, heat off: 1" to 2", VSWR 1.05/1

b. Approximate period of time ice or snow remained on the -

(1) Disc-cone antenna: 30 days

(2) FA-5676X antenna, heat on: No accumulation

(3) FA-5676X antenna, heat off: 1" on NW side for approximately one week

c. Was there any physical damage to the disc-cone antennas during winter 1965-1966: Five occasions

d. If so, to what extent: Disc lost on two antennas, cone elements lost on two antennas and base broken on one antenna

e. Was there any damage to the FA-5676X antenna during this period: No

IV. Coverage Performance

a. Was UHF coverage previously a problem at this frequency with the standard disc-cone antenna: No

b. With the prototype FA-5676X antenna were there any coverage problems: No

V. Other Comments, Ease of Maintenance, Safety of Maintenance, Photographs, Etc.

a. No maintenance required this winter. If removal of antenna should be required for maintenance, a minimum of two men would be required.

b. No reason presented during the test to indicate the thermostat controlling 115 V AC heater power was unreliable, however, the thermostat was by-passed per instructions received from Voice Communications Systems Branch, RD-220, January 27, 1966.

c. The heater was disconnected February 4, 1966, and operation continued under test until March 15, 1966.

VI. Recommendations on Modification for Production Version

a. None, satisfactory as is.